Supplement to NATURE

No. 2933 JANUARY 16, 1926

Wordsworth's Interpretation of Nature.[1]

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WORDSWORTH'S childhood and youth were spent with unusual freedom amid the sights and sounds of Nature, among hills and dales where inexhaustible variety of object and incident, grim as well as beautiful, is combined with an orderly repetition of conspicuous changes against a background of hard immutability. He revelled unchecked amid them all, "fostered alike by beauty and by fear."

His delight in Nature was closely akin to that which has inspired many famous naturalists, and his early sympathy with science was so clearly indicated that a slight turn of Fortune's wheel at the critical period of his life might well have made a naturalist of him instead of a poet. In 1785, when a happy schoolboy of fifteen, he eulogised from his Lakeland home

> those Elysian plains
> Where, throned in gold, immortal Science reigns,

and where Truth teaches

> the curious soul
> To search the mystic cause of things
> And follow Nature to her secret springs;

and he records that two years later, when an undergraduate at Cambridge, with rooms over the College kitchens at St. John's, nightly from his pillow he could see beneath the stars

> The antechapel where the statue stood
> Of Newton with his prism and silent face,—
> The marble index of a mind for ever
> Voyaging through strange seas of thought, alone.
> (The Prelude, III.)

His activities at Cambridge, however, remind one of Darwin's:

> We sauntered, played or rioted; we talked
> Unprofitable talk at morning hours;
> Drifted about along the streets and walks,
> Read lazily in trivial books, went forth
> To gallop through the country in blind zeal
> Of senseless horsemanship, or on the breast
> Of Cam sailed boisterously, and let the stars
> Come forth, perhaps without one quiet thought.

The academic fare, indeed, seems to have been of even less interest to him than to Darwin:

> I did not love,
> Judging not ill perhaps, the timid course
> Of our scholastic studies; could have wished
> To see the river flow with ampler range
> And freer pace.

A question here presents itself. Had there been a Henslow in those days to take this sensitive, sociable, aimless youth in hand, would Wordsworth and the world have gained or lost? It cannot be doubted that he was in a state of mind in which a very slight change in the course of events might have guided his contemplation of Nature into scientific rather than poetic channels.

It is undoubtedly a fact that geometry gave him great pleasure at this time as it did later:

> Specially delightful unto me
> Was that clear synthesis built up aloft
> So gracefully;
> (Prel. VI.)

and the tribute of the Sage in "The Excursion" to the happiness of the naturalist may safely be taken to represent the poet's own feelings:

> Happy is he who lives to understand
> Not human nature only, but explores
> All natures,—to the end that he may find
> The law that governs each, . . .
> Through all the mighty commonwealth of things
> Up from the creeping plant to sovereign man.
> (Exc. IV.)

This is exactly the spirit that animated Darwin, the curiosity that has animated the master-minds of every science. But it is as true of science as of literature, that "for the creation of a master-work . . . two powers must concur, the power of the man and the power of the moment, and the man is not enough without the moment." The conditions, themselves a chapter of accidents, which determined the play of Darwin's spirit, never fell to Wordsworth. None had realised more vividly than he the ordered character of the living as of the inanimate universe, and of the interrelations between them; but there was as yet no beginning even of a biological "synthesis" to attract his imagination. Observation of detail, which to a later age acquired

[1] Presidential address to the Leeds Philosophical and Literary Society, October 20, 1925 (slightly abbreviated by the author).

intellectual value, in Wordsworth's case simply enriched his emotions:

> Contented if he might enjoy
> The things which others understand.
> (The Poet's Epitaph, 1799.)

So no special science was to tie him down. This nursling of the "mountains, lakes and sounding cataracts" was "ill-tutored for captivity." But, haunted by dear memories, he did not altogether forget his old nurse; and Nature, if intermittently, continued to be his teacher. Of his Cambridge days, Wordsworth writes:

> Oft when the dazzling show no longer new
> Had ceased to dazzle, ofttimes did I quit
> My comrades, leave the crowd, buildings and groves,
> And as I paced alone the level fields
> Far from those lovely sights and sounds sublime
> With which I had been conversant, the mind
> Drooped not. . . .
> I looked for universal things; perused
> The common countenance of earth and sky.
> . . . . . .
> I called on both to teach me what they might;
> Or, turning the mind in upon herself,
> Pored, watched, expected, listened, spread my thoughts
> And spread them with a wider creeping; felt
> Incumbencies more awful, visitings
> Of the Upholder of the tranquil soul
> That tolerates the indignities of Time,
> And, from the centre of Eternity
> All finite motions overruling, lives
> In glory immutable . . . the great mass
> Lay bedded in a quickening soul, and all
> That I beheld respired with inward meaning.
> (Prel. III.)

This vision, a development of the more generalised emotions of earlier years,—this ecstatic realisation of the "One in all," was, if I mistake not, the spring and source of Wordsworth's interpretation of Nature. The slight fence between science and poetry had been crossed, and in the Parnassian direction:

> I had a world about me—'twas my own:
> I made it, for it only lived to me,
> And to the God who sees into the heart.

From his Cambridge time onwards, humanity began to encroach upon Nature as his principal object of interest, a period of residence in London, followed by a still more important one in France during the throes of the Revolution, contributing powerfully to this result. Though indifferent at first, he was drawn into the ferment, took sides with the "patriots," and threw himself whole-heartedly into the revolutionary cause, to be dismayed in due course when he realised

> The indecision on their part whose aim
> Seemed best, and the straightforward path of those
> Who in attack or in defence were strong
> Through their impiety.
> (Prel. X.)

Robespierre was still in power when Wordsworth was recalled to London ("dragged by a chain of harsh necessity") to undergo the mortification of hearing England's declaration of war on the Republic, the first of many moral shocks he was now to undergo. He had witnessed the ushering in, through garlanded streets and rainbow arches, of a Utopia of Reason, Liberty and Light, and, while for some years cherishing his faith in the cause, saw the issue in a long-drawn welter of conflicting passions that knew no test of good and bad, of what to hope for, or of what to shun, in which every one was doomed to become "the dupe of folly or the slave of crime." With instincts and knowledge adequate enough for his guidance along the beaten tracks, now that all these were obliterated the cheerful faith with which he set out faltered; he began to mistrust the very elevation of spirit which had linked him with

> Sage, warrior, patriot, hero; for it seemed
> That their best virtues were not free from taint
> Of something false and weak, that could not stand
> The open eye of Reason.
> (Prel. XII.)

He sought deliberately to separate his past by a complete "gulph" from the nebulous future before him, and in the check which his emotional life had sustained, threw poetic dreams and prospects overboard:

> In such strange passion I warred against myself—
> . . . . . .
> Zealously laboured to cut off my heart
> From all the sources of her former strength.

He turned to philosophy and found himself able, as he says, "by syllogistic words"

> to unsoul
> Those mysteries of Being which have made,
> And shall continue evermore to make,
> Of the whole human race one brotherhood;

and with remorseless logic scanned "even the visible Universe" with "microscopic view."

Simultaneously with this casting out of emotion, being "somewhat stern in temperament" and "bold to look on painful things," he made a renewed study of the whole framework of social life:

> Dragging all precepts, judgments, maxims, creeds,
> Like culprits to the bar; calling the mind,
> Suspiciously, to establish in plain day
> Her titles and her honours; now believing,
> Now disbelieving; endlessly perplexed
> With impulse, motive, right and wrong, the ground
> Of obligation, what the rule and whence
> The sanction; till, demanding formal *proof*,
> And seeking it in everything, I lost

All feeling of conviction, and, in fine,
Sick, wearied out with contrarieties,
Yielded up moral questions in despair.
(Prel. XI.)

The crisis was complete, and the upheaval of his life might well seem incapable of simple solution; yet it settled itself as quietly and insensibly as a wave of a summer sea. When Wordsworth returned to England after his two years in France, he was too deeply stirred to contemplate retirement to the country, and chose "the great City," where the general air was still agitated over the first unsuccessful attack on the slave trade. Here, as we have seen, he toiled through books and thoughts to find the solution of the problems of society which harassed him (1792–94). Finally, when he had brought himself to emptiness, hopelessness and scepticism, he turned to "abstract science" for relief and rejoined his sister Dorothy in Cumberland:

She whispered still that brightness would return;
She, in the midst of all, preserved me still
A Poet, made me seek beneath that name,
And that alone, my office upon earth;
And, lastly, . . . Nature's self,
By all varieties of human love
Assisted, led me back through opening day
To those sweet counsels between head and heart
Whence grew that genuine knowledge, fraught with peace,
Which, through the later sinkings of this cause,
Hath still upheld me, and upholds me now.
(Prel. XI.)

And this is how Nature worked:

Long time in search of knowledge did I range
The field of human life, in heart and mind
Benighted; but, the dawn beginning now
To reappear, 'twas proved that not in vain
I had been taught to reverence a Power
That is the visible quality and shape
And image of right reason; that matures
Her processes by steadfast laws; gives birth
To no impatient or fallacious hopes,
No heat of passion or excessive zeal,
No vain conceits; provokes to no quick turns
Of self-applauding intellect; but trains
To meekness, and exalts by humble faith;
Holds up before the mind intoxicate
With present objects, and the busy dance
Of things that pass away, a temperate show
Of objects that endure.
. . . . . .
Thus moderated, thus composed, I found
Once more in Man an object of delight,
Of pure imagination, and of love;
And, as the horizon of my mind enlarged,
Again I took the intellectual eye
For my instructor, studious more to see
Great truths, than touch and handle little ones.
Knowledge was given accordingly; my trust
Became more firm in feelings that had stood
The test of such a trial; clearer far
My sense of excellence—of right and wrong;
The promise of the present time retired
Into its true proportion; sanguine schemes,
Ambitious projects, pleased me less; I sought
For present good in life's familiar face,
And built thereon my hopes of good to come.
(Prel. XIII.)

Prof. Arthur Beatty, of Wisconsin, has recently published an elaborate study of Wordsworth's "Doctrine and Art in their Historical Relations," and makes one or two points which bear upon my topic. The poetic and doctrinal aspects of Wordsworth have frequently been regarded as hostile. Matthew Arnold, for example, "sought to establish the fame of the poet by ignoring his philosophy"; but the quotations I have given from "The Prelude" make it clear that with Wordsworth the attainment of a philosophy was essential to his poetry. In early youth he had caught the vision of the all-embracing unity of things, which was lost in France, and had to be regained before he could accomplish anything. He sought to get a true view of life as a whole, of man in relation to Nature, even as a part of Nature; and when he had acquired it, poetry was the expression of his attainment.

Philosophically, as Prof. Beatty claims, he revolted from the sentimental Rousseauist world into which he was born, or rather, into which he had strayed; and, poetically, he rebelled against the inflated language of his poetic predecessors. He was thus, in a twofold sense, a "poet of reaction," and the springs of both revolts were intimately related. His passion for reality and simplicity outside him had the same source as his love of truth and sincerity of thought within. These he himself attributed to his "education by Nature," which, as he says, from his "first dawn of childhood" did

interweave for me
The passions that build up our human soul
Not with the mean and vulgar works of man,
But with high objects, with enduring things—
With life and nature—purifying thus
The elements of feeling and of thought.
(Prel. I.)

For, having scanned,
Not heedlessly, the laws, and watched the forms
Of Nature, in that knowledge I possessed
A standard, often usefully applied,
Even when unconsciously, to things removed
From a familiar sympathy.
(Prel. V.)

But Prof. Beatty goes into detail, and is not content to see in the poet's attitude the simple flowering of the vigorous germs implanted in his fervent youth. "In the sphere of Art," says Beatty, "he revolts against poetic diction and harks back to Milton and Shakespeare and Chaucer; in Doctrine he revolts

against Rousseau and Godwin and appeals to Hartley, Locke, and the general tradition of English philosophy."

That Wordsworth followed Hartley and Locke in rejecting the doctrine of "innate ideas," and in recognising that early sensations and sense-impressions constitute the basis upon which the mind is built up by "association of ideas," Prof. Beatty has no difficulty in showing; but merely upon the evidences of this agreement, and of his frequent use of "associationist" language, to sum Wordsworth up as "the interpreter and poet of associationism" surely betrays a lack of perspective. So far as I can see, "associationism" was simply the ladder by which Wordsworth climbed out of the morass of sentimental idealism back to the point of view of his early vision:

> Ye motions of delight, that haunt the sides
> Of the green hills; ye breezes and soft airs,
> Whose subtle intercourse with breathing flowers,
> Feelingly watched, might teach Man's haughty race
> How without injury to take, to give
> Without offence; . . . Ye brooks
> Muttering along the stones, a busy noise
> By day, a quiet sound in silent night;
> Ye waves . . .
> And you, ye groves, . . .
> Oh, that I had a music and a voice
> Harmonious as your own, that I might tell
> What ye have done for me. The morning shines,
> Nor heedeth Man's perverseness; Spring returns,—
> *I saw the Spring return.*
>
> (Prel. XII.)

This surely is the poet of Nature that speaks, not the poet of "associationism" or any other philosophical nostrum.

Put briefly, the argument and illustrations detailed at great length in "The Prelude" amount to this, that man is not outside Nature—the universe of law and order—but by his subtlest fabric intimately bound up with it. Divorce him in youth from free contact with external Nature and you rob him of Nature's predetermined means of conferring upon him his share of her own grandeur, modesty and tranquillity. (See "The Three Ages" below.)

In the laws of association Wordsworth thus found not only his intellectual means of escape from sentimentalism and "innate ideas," but also confirmation of his original vision. We are all members of the all-uniting whole, and the very machinery of the mind's processes is a proof of it.

Nature, indeed, was to Wordsworth a universal symphony, a harmony of infinitely varied elements, appealing to man through every sense and gateway to the heart. Some of his smaller poems, and innumerable passages in his longer works, are just so many phrases and passages isolated from the general symphony for special purposes. The musical analogy crops up incessantly:

> No sound is uttered,—but a deep
> And solemn harmony pervades
> The hollow vale from steep to steep
> And penetrates the glades.
>
> A soft eye-music of slow-waving boughs.

There are dominating themes and *motifs*; alternations, contrasts and developments of grandeur, tumult and tranquillity; but the meanest instrument has its part to play:

> To every Form of Being is assigned
> An active Principle. (Exc. IX.)

But the activity or influence of a particular thing is not regarded as something rigorously fixed and definable, as the function of an organ or a species may be defined by science. In his most exalted moods, Wordsworth has his mind concentrated on the whole, and, when he considers the parts, it is their interrelations and interactions that he is conscious of, not their boundaries or limitations.

Herein lies the essential difference between the scientific and the Wordsworthian outlook. Wordsworth is listening to the symphony, contemplating the pageant; science, closing eyes and ears to both, is engrossed in the operations of the separate instruments, in the make-up and doings of the individual agents. The reward to science is an increasing command over instruments and materials for practical purposes, as well as a growing understanding of the processes by which the symphony is rendered. But any message which the symphony, in its entirety, has to convey, is lost to the merely analytic intellect, for it appeals to emotion, and is only apprehended by emotion. Wordsworth, following the symphony "in a wise passiveness," drinks in its "thousand blended notes," is caught up, as it were, into its atmosphere of grandeur, order and beauty, experiences an exaltation of joy that defies expression, and knows that he has entered a gateway to the loftiest aspects of reality open to man:

> With an eye made quiet by the power
> Of harmony, and the deep power of joy,
> We see into the life of things.
>
> (Tintern Abbey.)

The mere analyst shrugs his shoulders before a self revelation of this order, and suggests an abnormal activity of endocrine glands. The utmost that he is entitled to say is that the emotions, like thought itself, are conditioned, and that to wise men, in intellectual and practical matters, they have proved more useful as incentives than as guides—a truth which barely touches Wordsworth's claim, namely, the value for human life of high emotion ("admiration, hope, and love") when disciplined by communion with Nature in her varied moods, and balanced, not suppressed, by knowledge and reflection:

This is the freedom of the Universe
Unfolded, still the more, more visible,
The more we know.

On the lower plane of cause and effect there is no antagonism between the two points of view, for Wordsworth's belief embraces in advance everything that science has established or may establish as to the orderly and interdependent character of the universe, whether viewed from without or from within. But on the higher plane, in the life of the emotions or spirit, the necessitarian chain simply drops away, and is seen as a mere substratum, conditioning results but not causing them. So long as imagination, or "faith," maintains itself as "feeling" in that upper level, science, at any rate, can interpose no obstacles to its flight.

Take, as a test, this slight vignette:

A humming bee, a little trickling rill,
A pair of falcons wheeling on the wing.

The matter-of-fact man will see in these two lines a mere catalogue of three disconnected and trivial things of no significance; but to the Nature-lover they call up, with superb artistry, a fragment of the great world-symphony — summer peace with its muted sounds and leisured motions. To appreciate that fragment, or, better still, its original, is to enter, through the gateway of emotion, a realm in which the proudest generalisations of science are simply irrelevant.

It may be urged, and has been urged, that our so-called peace is a delusion, and that Wordsworth cannot expect us to ignore that underneath the apparent Nature, with which he deals, is a real Nature "red in tooth and claw." This pointed phrase, as every good naturalist knows, is based on a complete misunderstanding of the nature of the "struggle for existence," and suggests that animal life is maintained at the cost of great cruelty and suffering, which is simply not true. In reality, as in appearance, animal life is essentially a world of bustling activity and wide-spread enjoyment. Sooner or later death comes to one and all, but in most cases quickly and unconsciously, as Alfred Russel Wallace pointed out long ago. Only in man, because he "looks before and after," does death necessarily entail an undercurrent of sadness and tragedy.

How death came to be a condition of life is a biological question, to which a fairly clear answer, from the point of view of cause and effect, can already be provided. That it should ever be so has troubled sensitive souls for ages, but Wordsworth's identification of divine and natural laws enabled him to face the problem with the equanimity of a modern biologist:

Such ebb and flow must ever be,
Then wherefore should we mourn?
(Epitaphs, X., 1806.)

Our delight in the summer symphony may proceed, therefore, unchecked by any intellectual doubts as to the reality of the harmony presented to "eye and ear." That granted, no comment is needed on the supreme expression of Wordsworth's interpretation of the whole, except to notice how trouble and a richer human experience have softened the exuberance that glowed in the visionary moods of his youth:

For I have learned
To look on Nature, not as in the hour
Of thoughtless youth; but hearing oftentimes
The still, sad music of humanity,
Not harsh, nor grating, though of ample power
To chasten and subdue. And I have felt
A presence that disturbs me with the joy
Of elevated thoughts; a sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean and the living air,
And the blue sky, and in the mind of man;
A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things.
(Tintern Abbey.)

At this point it is natural and relevant to refer to an element in Wordsworth's doctrine which first finds expression in this beautiful poem, and plays a large and integral part in his conception of the relations between man and Nature — his emphasis on the distinctive qualities of the "Three Ages of Man." By tracing out, and correlating, the many passages, both of prose and verse, in which Wordsworth's ideas on this point are expressed, Prof. Beatty has discharged a critical task of great service to serious students of the poet. Stated briefly, and with special reference to my own theme, the point is this, that in the individual development of mind and character three stages are passed through: animal childhood (receptive and experimental); emotional (or "sentient") youth, and reflective (or "intellectual") maturity; and that, while each stage exhibits its own distinctive features, the mind only attains its complete fullness and efficiency if the earlier stages have been allowed free scope under conditions suited to make the most of their respective qualities—"The higher mode of being does not exclude, but necessarily includes, the lower: the intellectual does not exclude, but necessarily includes, the sentient; the sentient, the animal. . . ." (Wordsworth, "Convention of Cintra," 1809.)

The recognition of this principle doubtless came to Wordsworth during the period when he was clearing his mind after its unsettlement by his revolutionary experiences, and is bound up with his adoption of Hartley's "associationism." Its discovery, with all its implications, seems to have co-ordinated and stimulated the poet's thoughts and animated his

poetry, as profoundly as the theory of recapitulation affected the zoological world of a later generation. It was the idea of a necessary developmental sequence; and it not only resolved for him a number of hitherto perplexing problems, as set forth at length in "The Prelude," but also became the sheet-anchor of his perennial optimism, as exemplified in the fourth book of "The Excursion."

To it we owe not only its quintessential expression in "The Rainbow" (1802: "The Child is father of the Man"), and the sustained splendour of the famous Ode on "Intimations of Immortality" (1802–6), but also many other of the poet's most characteristic and sonorous lines:

> Dust as we are, the immortal spirit grows
> Like harmony in music. . . .
>
> (Prel. I.)

It is because the impressions incidentally received in childhood (*e.g.* during bathing, skating, trapping, nutting, etc.) may give so powerful a turn to the emotions of youth as to affect, for better or worse, the mind of manhood, that Wordsworth attaches so much importance to early association with Nature. The child is thus, under natural conditions, Nature's link between herself and man.

If the immortal "Ode" be re-read in the light of these remarks, it will be observed that the first four stanzas, which, according to Wordsworth himself, were written "two years at least" before the remainder, convey no sentiment at variance with this general idea. Indeed, this is just the idea which these four stanzas do so glowingly express—the identification of childhood with the glory and joy of Nature, and the more distant sympathy between Nature and manhood:

> The first diviner influence of this world,
> As it appears to unaccustomed eyes.
>
> (Prel. XII.)

The association of the idea of pre-existence with the "visionary gleam" of childhood was a "poetic" afterthought; and was intended, as Wordsworth himself has assured us, rather to emphasise than to explain the "dream-like" qualities of sight and feeling with which a child's mind explores the realities of the "not-self." In that case the poet very greatly overshot the mark, both by the extent to which he carried his apotheosis of the child, and by incorporating the idea in later versions of the title. Not all the poet's skill and sustained beauty of language have been able to blend the two voices speaking in this famous "Ode." In particular, as various critics have pointed out, the second group of four stanzas (v.-viii.) is, in effect, an interpolation, alien to the poet's whole philosophy of life, and inconsistent with both the opening and closing sections of the poem. By exaggerating the divinity of the child, he is compelled in those stanzas to treat the attainment of manhood in terms of loss instead of gain, whereas in the noble peroration of the "Ode," as well as everywhere else, the "years that bring the philosophic mind" are regarded as bringing with them an access of serenity and power and human sympathy which more than compensates for the loss of the "dizzy raptures" of youth.

It is remarkable that the zoological theory of "recapitulation" has undergone, and is still undergoing, the same criticism as that which has been applied to Wordsworth's "Ode," and is being steadily pruned of elements which exaggerate the ancestral significance of developmental features. In a brief criticism of the "Ode," the general result of which is not at variance with that expressed in my last paragraph, Dean Inge implies that the qualities of childhood, which Wordsworth exalts as reminiscences of its "ancestral home," may include racial instincts "which do not arise from his own (*i.e.* the child's) experience in his present life." So far as the "interpolated" stanzas are concerned, however, the reference is not just to "animal spirits," but to

> those obstinate questionings
> Of sense and outward things,
> Fallings from us, vanishings;
> Blank misgivings of a Creature
> Moving about in worlds unrealised;

and these, as is clear from the special incidents which Wordsworth recalls in his prefatory note, are not "ancestral" traits at all, but the inevitable reactions of any mind, in its first intense subjectivity, when groping its way to the perception of external reality. The more sensitive mind naturally reacts more strikingly.

From some of his more familiar poems it might be inferred that Wordsworth's attitude towards science was one of indifference, if not of contempt, *e.g.*

> Enough of Science and of Art;
> Close up those barren leaves.
>
> (Lyrical Ballads, 1798.)

This inference would not lack support from certain passages in "The Excursion" (Books III. and IV.).

It is equally true, however, that Wordsworth took a lofty view of the functions both of poetry and of science, and his tributes to the actual geometry and the potential biology of his time have already been quoted. In the famous preface to the second edition of "Lyrical Ballads" (1800), he tells us that the poet is as much concerned in the spread of truth as the man of science, but truth of a different and more general order, "not standing upon external testimony, but carried into the heart by passion, truth which is its own testimony, appealing to the knowledge which all men carry about with them, and to those sympathies in

which, without any other discipline than that of our daily life, we are fitted to take delight."

"The remotest discoveries of the Chemist, the Botanist, or Mineralogist, will be as proper objects of the Poet's art as any upon which it can be employed, if the time should ever come when these things shall be familiar to us, and the relations under which they are contemplated . . . shall be manifestly and palpably material to us as enjoying and suffering beings."

These quotations (nearly, but not quite, *verbatim*) are enough to show that, whether Wordsworth's point of view be accepted or not, he had a vision in his mind which was not unfriendly to the development of science, even though, as he said, he would be unable to make use of science until, in its various branches, it had made some degree of progress intelligible and familiar to the common man.

Passages like that already quoted from "Lyrical Ballads," or the half-sarcastic description in "The Excursion" (Bk. III.) of the botanist and the geologist of his time, are robbed of their sting when it is remembered that Wordsworth began to write in the eighteenth century, when few of the natural sciences had given any signal proof of their value to men "as enjoying and suffering beings." It was the age of Linneus, who was still alive in Wordsworth's youth. All the sciences were still at work upon their foundations, engrossed in distinguishing gases, analysing substances into their elements, describing and classifying species generally. They wore the aspect, to all but the initiated, of elegant pastimes or harmless hobbies.

It could scarcely be expected that the poet Wordsworth, appealing to emotion with a gospel of Nature that was the refined expression of vivid experience, should find an atmosphere "in which to move his wings" in analytic researches—

> Where soul is dead, and feeling hath no place;
> Where knowledge, ill begun in cold remark
> On outward things, with formal inference ends.
> (Exc. IV.)

Nevertheless, it was less the act of analysis than contentment with analysis that Wordsworth decried, and there are many passages in his later writings which suggest that his early appreciation of science grew stronger as time passed:

> To reinstate wild Fancy, would we hide
> Truths whose thick veil Science has drawn aside?
> (1833.)

Explicit references to scientific discoveries are not numerous, but the following are interesting examples of Wordsworth's poetic use of them. We have already noted his admiration of Newton. In his account of the babe in his mother's arms, he characteristically refers to "gravitation" as one of the bonds "that connect him [*i.e.* the babe] with the world" (Prel. II.).

In his poem "To the Small Celandine" (1803) there is a playful comparison between the poet's "discovery" of this flower and the stir made on the "sage astronomer's" finding of a new star. The allusion is obviously to Herschel's discovery of Uranus (1781).

Similarly, as was first pointed out to me by my blind botanical friend, Mr. J. G. Wilkinson, the poet's many references to the "breathing" of flowers—one of which has been quoted already (p. 4)—are probably based on the results of Joseph Priestley's experiments (1775)—"the philosophic Priestley" of Wordsworth's "Apology for the French Revolution" (1793). One of the poems which contains an allusion to "breathing flowers" is "This Lawn, a carpet all alive" (1829), and in the Fenwick note to this (1843) the poet remarks: "The beauty in form of a plant or an animal is not made less but more apparent as a whole by more accurate insight into its constituent properties and powers."

So far it has been possible to discuss Wordsworth's interpretation of Nature without considering the special use which the poet makes of particular details. We have seen, however, that while his general idea of Nature can be appropriately likened to that of a symphony, or, rather, an interacting harmony of sense-impressions generally, he also regarded each part of Nature, each "Form of Being," animate and inanimate, as discharging an "active" function. His clear, imaginative vision, and mastery of word and phrase, are never more telling than in those descriptions of Nature, scattered through all his larger works, in which the influences of natural objects are made manifest without the need of a single didactic word. As Matthew Arnold so aptly said: "Nature herself seems to take the pen out of his hand, and to write for him with her own bare, sheer, penetrating power."

When in his smaller poems Wordsworth singles out particular "Forms of Being" for special eulogy, a change of tone is at once apparent; the poet ceases to be the perfect mouthpiece of Nature, and, allowing freer play to fancy, tends to become the conscious teacher and moralist. It is not his special interest in "life's familiar face" that betrays him. On the contrary, to reveal new charms in the common-place strengthens his claims to be Nature's own interpreter. But Nature endows all her children with distinctive charms, each admirable in its sphere; and the false note creeps in when the moralist, with his single scale of human values, seeks to compare one flower with another, one bird with another, not from the relative efficiency with which they play their parts, but from their fancied approximation to points in the human code.

The Lesser Celandine, pleasing him at first, and naturally, as a bright harbinger of spring, becomes a type of meekness and humility in contrast to the self-advertising buttercup "of the flaring hours" (the "little children's flower" of Browning!). On the other hand the "cheerful" Daisy is praised for its very ubiquity at every season, while Violets "in their secret mews" ("modest" for every other poet!) are dismissed with a suggestion of encouraging the "wanton zephyrs." Similarly the fiery eloquence of the nightingale is rejected on one occasion for the "pensive" cooing of the stockdove, and on another for the "pilgrim" strains of the skylark, "true to the kindred points of heaven and home."

Treatment of this kind is obviously not interpretation of Nature, but self-expression, with natural objects employed as symbols. It differs little in essence from the "emblematic" treatment of Nature by the poet's predecessors, and carries with it an artificial flavour of the domestic garden, instead of the atmosphere of Nature herself. Even in these flights of fancy and imagination, however, Wordsworth always goes directly to Nature for his emblems and types, and not to the traditional stock, and his observant eye picks out real and distinctive features on which his reflections are based or his fancy plays.

As a typical example of this latter point may be cited his poem on the familiar "Herb Robert," with its shining red stems, which enable "Poor Robin," as he calls it,

> his part to fill;
> Cheerful alike if bare of flowers as now,
> Or when his tiny gems shall deck his brow.

But best of all his smaller Nature-poems, because simply lyrical, is, to my mind, his poem on the greenfinch ("Green Linnet"), in which he makes delightful play with the bird's liveliness, protective colouring, and characteristic discontinuity of song:

> My dazzled sight he oft deceives,
> A brother of the dancing leaves;
> Then flits, and from the cottage eaves
> Pours forth his song in gushes.

In fact, as the late Sir Walter Raleigh said, "the spirit of science has found no loftier or loyaller prophet than Wordsworth," and I venture to hope that this examination of Wordsworth's message and methods by one of themselves may not be altogether indifferent to the votaries of science. With zeal as undivided as theirs he pursued the same goal, truth; in accuracy and range of observation, no less than in fidelity of description, he was as scrupulous as the best, and equally critical (but not neglectful) of speculation and romance. Indeed, though poetic to the core, he risked reputation and fame by insisting that poetic creations must be based on the facts and realities of the world "as they are," and not as unchecked fancy may depict them—an axiom of his to which NATURE pays weekly tribute:

> To the solid ground
> Of Nature trusts the Mind that builds for aye;
> Convinced that there, there only, she can lay
> Secure foundations.
>
> (Misc. Sonnets, XXXIV.)

Wordsworth's whole gospel, indeed, might be summed up in some such terms as these: Learn the order of Nature; recognise the fixity of her laws, and then conform. Do these things, however, not with a cold and formal spirit, kicking against the pricks of stern necessity, but with a "feeling intellect" that first learns to admire the grandeur and harmony of Nature's order, and then aspires to achieve them in the distracted fields of human life:

> This prayer I make,
> Knowing that Nature never did betray
> The heart that loved her; 'tis her privilege
> Through all the years of this our life, to lead
> From joy to joy: for she can so inform
> The mind that is within us, so impress
> With quietness and beauty, and so feed
> With lofty thoughts, that neither evil tongues,
> Rash judgments, nor the sneers of selfish men,
> Nor greeting where no kindness is, nor all
> The dreary intercourse of daily life,
> Shall e'er prevail against us, or disturb
> Our cheerful faith, that all which we behold
> Is full of blessings.
>
> (Tintern Abbey, 1798.)

The facts confronting the poet and the man of science are the same, Nature and man,—man the inhabitant of Nature, and Nature the environment and nurse of man,—but each acting and reacting on the other, and together building up "this transcendent universe." To understand this unity is the task of poetry and science alike. But while science sets no term to its efforts, and the life-work of a single investigator is spent upon a mere fragment or two of the ultimate edifice, the poet, when he claims his ancient rôle, feels bidden to present to his age and generation a synthesis, of which the corners have been rounded by insight and feeling, where the inductions of science are still, and may be for ever, wanting. This aim may be incapable of complete attainment, but it is neither futile nor unwelcome in the attempt, provided the poet be equipped for his task by long, close and sympathetic converse with Nature and man, and that he be one

> who looks
> In steadiness, who hath among least things
> An undersense of greatest; sees the parts
> As parts, but with a feeling of the whole.

It is precisely because he fulfilled these requirements that Wordsworth still claims our attention.

Printed in Great Britain by R. & R. CLARK, LIMITED, *Edinburgh.*

Supplement to NATURE

No. 2936 FEBRUARY 6, 1926

Primitive Law and Order.[1]

By Dr. B. MALINOWSKI.

SAVAGERY to most people is still synonymous with absurd, cruel, and eccentric customs, with quaint superstitions and revolting practices. Sexual licence, infanticide, head-hunting, couvade, cannibalism and what not, have made anthropology attractive reading to many, a subject of curiosity rather than of serious scholarship to others. A fuller knowledge of the so-called savages, however, has revealed "Ye beastly devices of Ye heathen" as the product of firm law and of strict tradition, due to biological, mental and social needs of human nature, rather than as the outcome of unbridled passion and unfettered excess. Law and order pervade the tribal usages of primitive races, they govern all the humdrum course of daily existence, as well as the leading acts of public life, whether these be quaint and sensational or merely important and venerable.

The Automatic Submission to Custom and the Real Problem.

When we come to inquire why rules of conduct, however hard, irksome, or unwelcome, are obeyed; what makes private life, economic co-operation, public events run so smoothly; of what, in short, consist the forces of law and order in savagery—the answer is not so easy to give, and what anthropology has had to say about it is far from satisfactory. So long as it could be maintained that the 'savage' is really savage, that he follows what little law he has but fitfully and loosely, the problem did not exist. When the question became actual, when it became plain that hypertrophy of rules rather than lawlessness is characteristic of primitive life, scientific opinion casting for new bearings veered round to the opposite point: the savage was made not only into a model of the law-abiding citizen, but it also became an axiom that in submitting to all his tribal rules and fetters, he follows the natural trend of his spontaneous impulses; that in this way he glides, so to speak, along the line of least resistance.

The savage—so runs to-day's verdict of competent anthropologists—has a deep reverence for tradition and custom, an automatic submission to their biddings. He obeys them "slavishly," "unwittingly," "spontaneously," through "mental inertia," combined with the fear of public opinion or of supernatural punishment (Sidney Hartland); or again through a "pervading group-sentiment if not group-instinct" (Rivers). I have already in a previous article stated the views of such contemporary writers as Hobhouse, Rivers, Sidney Hartland and Lowie, and I have submitted them to a searching criticism and have arrived at the conclusion that neither the way in which the problem has been set forth, nor the solutions given, can be regarded as adequate.[2] I have also tried to make it clear that any shortcomings in theory or observation are due to the real difficulties and pitfalls of which this subject is so full.

The extreme difficulty of the problem lies, I think, in the very complex and diffuse nature of the forces which constitute primitive law. Accustomed as we are to look for a definite machinery of enactment, administration, and enforcement of law, we cast round for something analogous in a savage community and, failing to find there any similar arrangements, we conclude that all law is obeyed by this mysterious propensity of the savage to obey it.

Anthropology seems here to be faced by a similar difficulty as the one overcome by Tylor in his "minimum definition of religion." By defining the forces of law in terms of central authority, codes, courts, and constables, we must come to the conclusion that law needs no enforcement in a primitive community and is followed spontaneously. That the savage does break the law sometimes, though rarely and occasionally, has been recorded by observers and taken into account by builders of anthropological theory, who have always maintained that criminal law is the only law of savages. But that his observance of the rules of law under the normal conditions, when it is followed and not defied, is at best partial, conditional, and subject to evasions; that it is not enforced by any wholesale motive like fear of punishment, or a general submission to all tradition, but by very complex psychological and social inducements—all this is a state of affairs which modern

[1] The present article contains the substance, expanded and recast, of a discourse delivered before the Royal Institution on Friday, February 13, 1925. I wish to express my indebtedness to the Laura Spelman Rockefeller Memorial for the assistance given me in carrying out this investigation.

[2] See NATURE, August 15, 1925, p. 230, review entitled "Primitive Law."

anthropology has so far completely overlooked. In the following account I shall try to establish it for one ethnographic province, north-west Melanesia, and I shall show reasons why observations of similar nature to those carried out by myself should be extended to other societies in order to give us some idea about their legal conditions.

We shall approach our facts with a very elastic and wide conception of the problem before us. In looking for 'law' and legal forces, we shall try merely to discover and analyse all the rules conceived and acted upon as binding obligations, to find out the nature of the binding forces, and to classify the rules according to the manner in which they are made valid. We shall see that by an inductive examination of facts, carried out without any preconceived idea or ready-made definition, we shall be enabled to arrive at a satisfactory classification of the norms and rules of a primitive community, at a clear distinction of primitive law from other forms of custom, and at a new, dynamic conception of the social organisation of savages. Since the facts of primitive law described in this article have been recorded in Melanesia, the classical area of 'communism' and 'promiscuity,' of 'group-sentiment' and 'clan-solidarity,' of 'spontaneous obedience' and what not, the conclusions we shall be able to draw—which will dispose of these catch-words and all they stand for—may be of special interest.

Melanesian Economics and the Theory of Primitive Communism.

The Trobriand Archipelago, which is inhabited by the Melanesian community referred to, lies to the north-east of New Guinea and consists of a group of flat coral islands, surrounding a wide lagoon. The plains of the land are covered with fertile soil and the lagoon teems with fish, while both afford easy means of intercommunication to the inhabitants. Accordingly, the islands support a dense population mainly engaged in agriculture and fishing, but expert also in various arts and crafts and keen on trade and exchange.

Like all coral islanders, they spend a great deal of their time on the central lagoon. On a calm day it is alive with canoes carrying people or produce, or engaged in one of their manifold systems of fishing. A superficial acquaintance with these pursuits might leave one with an impression of arbitrary disorder, anarchy, complete lack of system. Patient and painstaking observations would soon reveal, however, not only that the natives have definite technical systems of catching fish and complex economic arrangements, but also that they have a close organisation in their working teams, and a fixed division of social functions.

Thus, within each canoe it would be found that there is one man who is its rightful owner, while the rest act as a crew. All these men, who as a rule belong to the same sub-clan, are bound to each other and to their fellow-villagers by mutual obligations: when the whole community go out fishing, the owner cannot refuse his canoe. He must go out himself or let some one else do it instead. The crew are equally under an obligation to him. For reasons which will presently become clear, each man must fill his place and stand by his task. Each man also receives his fair share in the distribution of the catch as an equivalent of his service. Thus the ownership and the use of the canoe consist of a series of definite obligations and duties uniting a group of people into a working team.

What makes the conditions even more complex is that the owners and the members of the crew are entitled to surrender their privileges to any one of their relatives and friends. This is often done, but always for a consideration, for a repayment. To an observer who does not grasp all the details, and does not follow all the intricacies of each transaction, such a state of affairs looks very much like communism: the canoe appears to be owned jointly by a group and used indiscriminately by the whole community.

Dr. Rivers in fact tells us that "one of the objects of Melanesian culture which is usually, if not always, the subject of common ownership is the canoe," and further on, in reference to this statement, he speaks about "the great extent to which communistic sentiments concerning property dominate the people of Melanesia" ("Social Organisation," pp. 106 and 107). In another work, the same writer speaks about "the socialistic or even communistic behaviour of such societies as those of Melanesia" ("Psychology and Politics," pp. 86 and 87). Nothing could be more mistaken than such generalisations. There is a strict distinction and definition in the rights of every one, and this makes ownership anything but communistic. We have in Melanesia a compound and complex system of holding property, which in no way partakes of the nature of 'socialism' or 'communism.' A modern joint-stock company might just as well be called a 'communistic enterprise.' As a matter of fact, any descriptions of a savage institution in terms such as 'communism,' 'capitalism,' 'joint-stock company,' or what not, borrowed from present-day economic conditions or political controversy, cannot be but misleading.

The only correct proceeding is to describe the legal state of affairs in terms of concrete fact. Thus, the ownership of a Trobriand fishing canoe is defined by the manner in which the object is made, used and regarded with reference to the group of men who produced it and enjoy its possession. The master of the canoe,

who acts at the same time as the head of the team and as the fishing magician of the canoe, has first of all to finance the building of a new craft, when the old one is worn out, and he has to maintain it in good repair, helped in this by the rest of his crew. In this they remain under mutual obligations to one another, to appear each at his post, while every canoe is bound to come when a communal fishing has been arranged.

In using the craft, every joint owner has a right to a certain place in it and to certain duties, privileges, and benefits associated with it. He has his post in the canoe, he has his task to perform, and enjoys the corresponding title, either of 'master' or 'steersman,' or 'keeper of the nets,' or 'watcher for fish.' His position and title are determined by the combined action of rank, age, and personal ability. Each canoe also has its place in the fleet and its part to play in the manœuvres of joint fishing. Thus on a close inquiry we discover in this pursuit a definite system of division of functions and a rigid system of mutual obligations, into which a sense of duty and the recognition of the need of co-operation enter side by side with a realisation of self-interest, privileges, and benefits. Ownership, therefore, can be defined neither by such words as 'communism' or 'individualism,' nor by reference to 'joint-stock company' system or 'personal enterprise,' but by the concrete facts and conditions of use. It is the sum of duties, privileges, and mutualities which bind the joint owners to the object and to each other.

Thus, in connexion with the first object which attracted our attention—the native canoe—we are met by law, order, definite privileges, and a well-developed system of obligations.

The Binding Force of Economic Obligations.

To enter more deeply into the nature of these binding obligations, let us follow the fishermen to the shore. Let us see what happens with the division of the catch. In most cases only a small proportion of it remains with the villagers. As a rule we should find a number of people from some inland community waiting on the shore. They receive the bundles of fish from the fisherman and carry them home, often many miles away, running so as to arrive while it is still fresh. Here again we should find a system of mutual services and obligations based on a standing arrangement between two village communities. The inland village supplies the fishermen with vegetables: the coastal community repays with fish. This arrangement is primarily an economic one. It has also a ceremonial aspect, for the exchange has to be done according to an elaborate ritual. But there is also the legal side, a system of mutual obligations which forces the fisherman to repay whenever he has received a gift from his inland partner, and vice versa. Neither partner can refuse, neither may stint in his return gift, neither should delay.

What is the motive force behind these obligations? The coastal and inland villages respectively have to rely upon each other for the supply of food. On the coast the natives never have enough vegetable food, while inland the people are always in need of fish. Moreover, custom will have it that on the coast all the big ceremonial displays and distributions of food, which form an extremely important aspect of the public life of these natives, must be made with certain specially large and fine varieties of vegetable food, which grow only on the fertile plains inland. There, on the other hand, the proper substance for a distribution and feast is fish. Thus to all other reasons of value of the respectively rarer food, there is added an artificially, culturally created dependence of the two districts upon one another. So that on the whole each community is very much in need of its partners. If at any time previously these have been guilty of neglect, however, they know that they will be in one way or another severely penalised. Each community has, therefore, a weapon for the enforcement of its rights: reciprocity.

This is not limited to the exchange of fish for vegetables. As a rule, two communities rely upon each other in other forms of trading and other mutual services as well. Thus every chain of reciprocity is made the more stringent by being part and parcel of a whole system of mutualities.

Reciprocity and Dual Organisation.

I have found only one writer who fully appreciates the importance of reciprocity in primitive social organisation. The leading German anthropologist, Prof. Thurnwald of Berlin, clearly recognises "die Symmetrie des Gesellschaftsbaus" and the corresponding "Symmetrie von Handlungen." "Die Symmetrie von Handlungen aber nennen wir das Prinzip der Vergeltung. Dieses liegt tief verwurzelt im menschlichen Empfinden—als adäquate Reaktion—und ihm kam von jeher die grösste Bedeutung im sozialen Leben zu" ("Die Gemeinde der Bánaro," Stuttgart, 1921, p. 16). Throughout his monograph, which by the way is perhaps the best account of the social organisation of a savage tribe extant, Prof. Thurnwald shows how the symmetry of social structure and of actions pervades native life. Its importance as a legal binding form is not, however, explicitly stated by the writer, who seems to be aware of its psychological foundation "in human feeling" rather than of its social function in safeguarding the continuity and adequacy of mutual services.

The old theories of tribal dichotomy, the discussions about the 'origins' of 'phratries' or 'moieties' and of the duality in tribal subdivisions, never entered into the inner or differential foundations of the external phenomenon of halving. The recent treatment of the "dual organisation" by the late Dr. Rivers and his school suffers badly from the defect of looking for recondite causes instead of analysing the phenomenon itself. The dual principle is neither the result of "fusion" or "splitting" nor of any other sociological cataclysm. It is the integral result of the inner symmetry of all social transactions, of the reciprocity of services, without which no primitive community could exist. A dual organisation may appear clearly in the division of a tribe into two 'moieties' or be almost completely obliterated—but I venture to foretell that wherever careful inquiry be made, symmetry of structure will be found in every savage society, as the indispensable basis of reciprocal obligations.

The sociological manner in which the relations of reciprocity are arranged makes them yet more stringent. Between the two communities the exchanges are not carried out haphazard, any two individuals trading with each other at random. On the contrary, every man has his permanent partner in the exchange, and the two have to deal with each other. They are often relatives-in-law, or else sworn friends, or partners in the important system of ceremonial exchange called *kula*. Within each community again, the individual partners are ranged into totemic subclans. So that the exchange establishes a system of sociological ties of economic nature, often combined with other ties, between individual and individual, kinship group and kinship group, village and village, district and district.

Going over the relations and transactions previously described, it is easy to see that the same principle of mutuality supplies the sanction to each rule. There is in every act as well as at the basis of every status a sociological dualism: two parties who exchange services and functions, each watching over the measure of fulfilment and the fairness of conduct of the other. The master of the canoe, whose interests and ambitions are bound up with his craft, looks after order in the internal transactions between the members of the crew and represents the latter externally. To him each member of the crew is bound at the time of construction and ever after, when co-operation is necessary. Reciprocally, the master has to give each man the ceremonial payment at the feast of construction; the master cannot refuse any one his place in the boat; and he has to see that each man receives his fair share of the catch. In this and in all the manifold activities of economic order, the social behaviour of the natives is based on a well-assessed give-and-take, always mentally ticked off and in the long run balanced. There is no wholesale discharge of duties or acceptance of privileges; no 'communistic' disregard of tally and ear-mark. The free and easy way in which all transactions are done, the good manners which pervade all and cover any hitches or maladjustments, make it difficult for the superficial observer to see the keen self-interest and watchful reckoning which runs right through. To one who knows the natives intimately, nothing is more patent than this. The same control which the master assumes within his canoe, is taken within the community by the headman who is, as a rule, also the hereditary magician.

Law, Self-interest, and Social Ambition.

It scarcely needs to be added that there are also other driving motives, besides the constraint of reciprocal obligations, which keep the fishermen to their task. The utility of the pursuit, the craving for the fresh, excellent diet, above all, perhaps, the fascination of what to the natives is an intensely fascinating sport—move them more obviously, more consciously even, and more effectively than what we have described as the legal obligation. But the social constraint, the regard for the effective rights and claims of others is always prominent in the mind of the natives as well as in their behaviour, once this is well understood. It is also indispensable to ensure the smooth working of their institutions. For in spite of all zest and attractions, there are on each occasion a few individuals, indisposed, moody, obsessed by some other interest—very often by an intrigue—who would like to escape from their obligation, if they could. Any one who knows how extremely difficult, if not impossible, it is to organise a body of Melanesians for even a short and amusing pursuit requiring concerted action, and how well and readily they set to work in their customary enterprises, will realise the function and the need of compulsion, due to the native's conviction that another man has a claim on his work.

There is yet another force which makes the obligations still more binding. I have mentioned already the ceremonial aspect of the transactions. The gifts of food in the system of exchange described above must be offered according to strict formalities, in specially made measures of wood, carried and presented in a prescribed manner, in a ceremonial procession and with a blast of conch-shells. Now nothing has a greater sway over the Melanesian's mind than ambition and vanity associated with a display of food and wealth. In the giving of gifts, in the distribution of their surplus, they feel a manifestation of power, and an enhancement of personality. The Trobriander keeps his food in houses better made and more highly ornamented

than his dwelling huts. Generosity is the highest virtue to him, and wealth the essential element of influence and rank. The association of a semi-commercial transaction with definite public ceremonies supplies another binding force of fulfilment through a special psychological mechanism: the desire for display, the ambition to appear munificent, the extreme esteem for wealth and for the accumulation of food.

We have thus gained some insight into the nature of the mental and social forces which make certain rules of conduct into binding law. Nor is the binding force superfluous. Whenever the native can evade his obligations without the loss of prestige, or without the prospective loss of gain, he does so, exactly as a civilised business man would do. When the "automatic smoothness" in the run of obligations so often attributed to the Melanesian is studied more closely, it becomes clear that there are constant hitches in the transactions, that there is much grumbling and recrimination and seldom is a man completely satisfied with his partner. But, on the whole, he continues in the partnership and, on the whole, every one tries to fulfil his obligations, for he is impelled to do so, partly through enlightened self-interest, partly in obedience to his social ambitions and sentiments. Take the real savage, keen on evading his duties, swaggering and boastful when he has fulfilled them, and compare him with the anthropologist's dummy who slavishly follows custom and automatically obeys every regulation. There is not the remotest resemblance between the teachings of anthropology on this subject and the reality of native life. We begin to see how the dogma of mechanical obedience to law would prevent the field-worker from seeing the really relevant facts of primitive legal organisation. We understand now that the rules of law, the rules with a definite binding obligation, stand out from the mere rules of custom. We can see also that civil law, consisting of positive ordinances, is much more developed than the body of mere prohibitions, and that a study of criminal law alone among savages misses the most important phenomena of their legal life.

It is also obvious that the type of rules which we have been discussing, although they are unquestionably rules of binding law, have in no way the character of religious commandments, laid down absolutely, obeyed rigidly and integrally.[3] The rules here described are essentially elastic, adjustable, and they leave a considerable latitude within which their fulfilment is regarded as satisfactory. The bundles of fish, the measures of yams, or bunches of taro, can only be roughly assessed, and naturally the quantities exchanged vary according to whether the fishing season or the harvest is more abundant. All this is taken into account and only wilful stinginess, neglect, or laziness are regarded as a breach of contract. Since again, largesse is a matter of honour and praise, the average native will strain all his resources to be lavish in his measure. He knows, moreover, that any excess in zeal and generosity is bound to be sooner or later rewarded.

We can see now that a narrow and rigid conception of the problem—a definition of 'law' as the machinery of carrying out justice in cases of trespass—would leave on one side all the phenomena to which we have referred. In all facts described, the element or aspect of law, that is, of effective social constraint, consists in the complex arrangements which make people keep to their obligations. Among them the most important is the manner in which many transactions are linked into chains of mutual services, every one of them having to be repaid at some later date. The public and ceremonial manner in which these transactions are usually carried out, combined with the great ambition and vanity of the Melanesian, adds also to the safeguarding forces of law.

The Rules of Law in Religious Acts.

I have referred so far mainly to economic relations, for civil law is primarily concerned with ownership and wealth among savages as well as among ourselves. But we could find the legal aspect in any other domain of tribal life. Take, for example, the most characteristic acts of ceremonial life—the rites of mourning and sorrow for the dead. At first we perceive in them, naturally, their religious character: they are acts of piety towards the deceased, caused by fear or love or solicitude for the spirit of the departed. As ritual and public display of emotion, they are also part of the ceremonial life of the community.

Who, however, would suspect a legal side to such religious transactions? Yet in the Trobriands there is not one single mortuary act, not one ceremony, which is not considered to be an obligation of the performer towards some of the other survivors. The widow weeps and wails in ceremonial sorrow, in religious piety and fear—but also because the strength of her grief affords direct satisfaction to the deceased man's brothers and maternal relatives. It is the matrilineal group of kindred who, according to the native theory of kinship and mourning, are the people really bereaved. The wife, though she lived with her husband, though she should grieve at his death, though often she really and sincerely does so, remains but a stranger, by the rules of matrilineal kinship. It is her duty towards the surviving members of her husband's clan, accordingly, to display her grief, to keep a long period of mourning

[3] Examples of scientific opinions, which ascribe to primitive law in general such a semi-religious character, are given in the review entitled "Primitive Law," referred to above.

and to carry the jaw-bone of her husband for some years after his death. Nor is this obligation without reciprocity. At the first big ceremonial distribution, some three days after her husband's death, she will receive from his kinsmen a ritual payment, and a substantial one, for her tears; and at later ceremonial feasts she is given more payments for the subsequent services of mourning. It should also be kept in mind that, to the natives, mourning is but a link in the lifelong chain of reciprocities between husband and wife and between their respective families.

The Law of Marriage.

This brings us to the subject of marriage, extremely important for the understanding of native law. Marriage establishes not merely a bond between husband and wife, but it also imposes a standing relation of mutuality between the man and the wife's family, especially her brother. A woman and her brother are bound to each other by characteristic and highly important ties of kinship. In a Trobriand family a female must always remain under the special guardianship of one man—one of her brothers or, if she has none, her nearest maternal kinsman. She has to obey him and fulfil a number of duties, while he looks after her welfare and provides for her economically even after she is married.

The brother becomes the natural warden of her children, who therefore have to regard him and not their father as the legal head of the family. He in turn has to look after them, and he has to supply the household with a considerable proportion of its food. This is the more burdensome since marriage being patrilocal, the girl has moved away to her husband's community, so that every time at harvest there is a general economic *chassé-croisé* all over the district.

After the crops are taken out, the yams are classified and the pick of the crop from each garden is put into a conical heap. The main heap in each garden plot is always for the sister's household. The sole purpose of all the skill and labour devoted to this display of food is the satisfaction of the gardener's ambition. The whole community, nay, the whole district, will see the garden produce, comment upon it, criticise, or praise. A big heap proclaims, in the words of my informant: "Look what I have done for my sister and her family. I am a good gardener and my nearest relatives, my sister and her children, will never suffer for want of food." After a few days the heap is dismantled, the yams carried in baskets to the sister's village, where they are put up into exactly the same shape in front of the yamhouse of the sister's husband; there again the members of the community will see the heap and admire it. This whole ceremonial side of the transaction has a binding force which we know already. The display, the comparisons, the public assessment impose a definite psychological constraint upon the giver—they satisfy and reward him, when successful work enables him to give a generous gift, and they penalise and humiliate him for inefficiency, stinginess, or bad luck.

Besides ambition, reciprocity prevails in this transaction as everywhere else; at times, indeed, it steps in almost upon the heels of an act of fulfilment. First of all, the husband has to repay by definite periodic gifts every annual harvest contribution. Later on, when the children grow up, they will come directly under the authority of their maternal uncle; the boys will have to help him, to assist him in everything, to contribute a definite quota to all the payments he has to make. His sister's daughters do but little for him directly, but indirectly, in a matrilineal society, they provide him with his heirs and descendants of two generations below.

Thus placing the harvest offerings within their sociological context, and taking a long view of the relationship, we see that every one of its transactions is justified as a link in the chain of mutualities. Yet taking it isolated, torn out of its setting, each transaction appears nonsensical, intolerably burdensome and, sociologically, meaningless, also no doubt "communistic"! What could be more economically absurd than this oblique distribution of garden produce, where every man works for his sister and has to rely in turn on his wife's brother, where more time and energy is apparently wasted on display, on show, on the shifting of the goods, than on real work? Yet a closer analysis shows that some of these apparently unnecessary actions are powerful economic incentives, that others supply the legal binding force, while others again are the direct result of native kinship ideas. It is also clear that we can understand the legal aspect of such relations only if we look upon them integrally without over-emphasising any one link in the chain of reciprocal duties.

The real reason why all these economic obligations are normally kept, and kept very scrupulously, is that failure to comply places a man in an intolerable position, while slackness in fulfilment covers him with opprobrium. The honourable citizen is bound to carry out his duties, though his submission is not due to any instinct or intuitive impulse or mysterious 'group-sentiment,' but to the detailed and elaborate working of a system, in which every act has its own place and must be performed without fail. Though no native, however intelligent, can formulate this state of affairs in a general, abstract manner, or present it as a sociological theory, yet every one is well aware of its exist-

ence, and in each concrete case he can foresee the consequences.

The Rules of Custom defined and classified.

If we designate the sum total of rules, conventions, and patterns of behaviour as the body of custom, there is no doubt that the native feels a strong respect for all of them, has a tendency to do what others do, what every one approves of, and, if not drawn or driven in another direction by his appetites or interests, will follow the biddings of custom rather than any other course. The force of habit, the awe of traditional command and a sentimental attachment to it, the desire to satisfy public opinion—all combine to make custom be obeyed for its own sake. In this the 'savages' do not differ from the members of any self-contained community with a limited horizon, whether this be an Eastern European ghetto, an Oxford college, or a Fundamentalist Middle West community. But love of tradition, conformism, and the sway of custom account but to a very partial extent for obedience to rules among dons, savages, peasants, or Junkers.

Limiting ourselves strictly to savages once more, there are among the Trobrianders a number of traditional rules instructing the craftsman how to ply his trade. The inert and uncritical way in which these rules are obeyed is due to the general 'conformism of savages' as we might call it. But in the main these rules are followed because their practical utility is recognised by reason and testified by experience. Again, other injunctions of how to behave in associating with one's friends, relatives, superiors, equals, and so on, are obeyed because any deviation from them makes a man feel and look, in the eyes of others, ridiculous, clumsy, socially uncouth. These are the precepts of good manners, very developed in Melanesia and most strictly adhered to. There are further rules laying down the proceedings at games, sports, entertainments and festivities, rules which are the soul and substance of the amusement or pursuit and are kept because it is felt and recognised that any failure to 'play the game' spoils it—that is, when the game is really a game! In all this, it will be noted, there are no mental forces of inclination or of self-interest, or even inertia, which would run counter to any rule and make its fulfilment a burden. It is quite as easy to follow the rule as not, and once you embark upon a sporting or pleasurable pursuit, you really can enjoy it only if you obey all its rules whether of art, manner, or game.

There are also norms pertaining to things sacred and important, the rules of magical rite, funerary pomp, or what not. These are primarily backed up by supernatural sanctions and by the strong feeling that sacred matters must not be tampered with. By an equally strong moral force are maintained certain rules of personal conduct towards near relatives, members of the household and others towards whom strong sentiments of friendship, loyalty, or devotion are felt, which back up the dictates of the social code.

This brief catalogue is not an attempt at a classification, but is mainly meant to indicate clearly that, besides the rules of law, there are several other types of norm and traditional commandment which are backed up by motives or forces, mainly psychological, in any case entirely different from those which are characteristic of law in that community. Thus, though in my survey attention has naturally been mainly focussed on the legal machinery, I was not intent on proving that all social rules are legal, but on the contrary, I wanted to show that the rules of law form but one well-defined category within the body of custom.

An Anthropological Definition of Law.

The rules of law stand out from the rest in that they are felt and regarded as the obligations of one person and the rightful claims of another. They are sanctioned not by a mere psychological motive, but by a definite social machinery of binding force, based, as we know, upon mutual dependence and realised in the equivalent arrangement of reciprocal services, as well as in the combination of such claims into strands of multiple relationship. The ceremonial manner in which most transactions are carried out, which entails public control and criticism, adds still more to their binding force.

We may therefore finally dismiss the view that 'group-sentiment' or 'collective responsibility' are the only or even the main force which ensures adhesion to custom and which makes it binding or legal. *Esprit de corps*, solidarity, pride in one's community and clan exist undoubtedly among the Melanesians—no social order could be maintained without them in any culture high or low. I only want to enter a caution against such exaggerated views as those of Rivers, Sidney Hartland, Durkheim, and others, which would make this unselfish, impersonal, unlimited group-loyalty the corner-stone of all social order in primitive cultures. The savage is neither an extreme 'collectivist' nor an intransigent 'individualist'—he is, like man in general, a mixture of both.

It results also from the account here given that primitive law does not consist exclusively or even mostly of negative injunctions, nor is all savage law criminal law.[4] So far we have met with positive commandments only, the breach of which is penalised but not punished, and the machinery of which can by no procrustean methods be stretched beyond the line

[4] Quotations of such opinions in modern anthropological literature and a criticism of them is given in the review entitled "Primitive Law," referred to above.

which separates *civil* from *criminal* law. If we have to provide the rules described in these articles with some modern, hence necessarily inappropriate, label, they must be called the body of 'civil law' of the Trobriand Islanders.

'Civil law,' the positive law governing all the phases of tribal life, consists then of a body of binding obligations, regarded as a right by one party and acknowledged as a duty by the other, kept in force by a specific mechanism of reciprocity and publicity, inherent in the structure of their society. These rules of civil law are elastic and possessing a certain latitude. They offer not only penalties for failure, but also premiums for an overdose of fulfilment. Their stringency is ensured through the rational appreciation of cause and effect by the natives, combined with a number of social and personal sentiments such as ambition, vanity, pride, desire of self-enhancement by display, and also attachment, friendship, devotion and loyalty to the kin.

It scarcely needs to be added that 'law' and 'legal phenomena,' as we have discovered, described, and defined them in a part of Melanesia, do not consist in any independent institutions. Law represents rather an aspect of their tribal life, one side of their structure, than any independent, self-contained social arrangements. Law dwells not in a special system of decrees, which foresee and define possible forms of non-fulfilment and provide appropriate barriers and remedies. Law is the specific result of the configuration of obligations, which makes it impossible for the native to shirk his responsibility without suffering for it in the future.

Specific Legal Arrangements.

The rare quarrels which occur at times take the form of an exchange of public expostulation (*yakala*), in which the two parties assisted by friends and relatives meet, harangue one another, hurl and hurl back recriminations. Such litigation allows people to give vent to their feelings and shows the trend of public opinion, and thus it may be of assistance in settling disputes. Sometimes it seems, however, only to harden the litigants. In no case is there any definite sentence pronounced by a third party, and agreement is but seldom reached then and there. The *yakala* therefore is a special legal arrangement, but of small importance and not really touching the heart of legal constraint.

Some other specific legal mechanisms may also be mentioned here. One of them is the *kaytapaku*, the magical protection of property by means of conditional curses. When a man owns coco or areca palms in distant spots, where it is impossible to keep watch over them, he attaches a palm leaf to the trunk of the tree, an indication that a formula has been uttered, which automatically would bring down ailment on the thief. Another institution which has a legal side is the *kaytubutabu*, a form of magic performed over all the coconut trees of a community to bring about their fertility, as a rule in view of an approaching feast. Such magic entails a strict prohibition to gather the nuts or to partake of coconut, even when imported. A similar institution is the *gwara*.[5] A pole is planted on the reef, and this places a taboo on any export of certain valuable objects, exchanged ceremonially in the *kula*, while their importation on the contrary is encouraged. This is a sort of moratorium, stopping all payments, without any interference with the receipts, which also aims at an accumulation of valuable objects before a big ceremonial distribution. Another important legal feature is a sort of ceremonial contract, called *kayasa*.[6] Here the leader of an expedition, the master of a feast, or the *entrepreneur* in an industrial venture, gives a big ceremonial distribution. Those who participate in it and benefit by the bounty are under an obligation to assist the leader throughout the enterprise.

All these institutions, *kayasa*, *kaytapaku*, and *kaytubutabu*, entail special binding ties. But even they are not exclusively *legal*. It would be above all a great mistake to deal with the subject of law by a simple enumeration of these few arrangements, each of which subserves a special end and fulfils a very partial function. The main province of law is in the social mechanism which is to be found at the bottom of all the real obligations and covers a very vast portion of their custom, though by no means all of it, as we know.

Conclusion and Forecast.

I have dealt here only with one province of Melanesia, and the conclusions arrived at have naturally a limited range. These conclusions, however, are based on facts observed by a new method and regarded from a new point of view, so that they might stimulate other observers to take up a similar line of study in other parts of the world. With a wider and more elastic 'minimum definition' of law, there is no doubt that new legal phenomena of the same type as those found in N.W. Melanesia will be discovered. There is no doubt that custom is not based only on a universal, undifferentiated, ubiquitous force, this mental inertia, though this unquestionably exists and adds its quota to other constraint. There must be in all societies a class of rules too practical to be backed up by religious sanctions, too burdensome to be left to mere goodwill, too personally vital to individuals to be enforced by any abstract agency. This is the domain of legal rules, and I venture to foretell that reciprocity, systematic incidence, publicity and ambition will be found to be the main factors in the binding machinery of primitive law.

[5] Comp. the account of this institution in "Argonauts of the Western Pacific" (references in Index s.v. *Gwara*); also descriptions in Prof. Seligman's "Melanesians," and in the present writer's "The Natives of Mailu" (*Trans. R. Soc. of S. Australia*, vol. 39), of the *gola* or *gora* among the Western Papuo-Melanesians.

[6] "Argonauts of the Western Pacific." See in Index s.v. *Kayasa*.

Printed in Great Britain by R. & R. Clark, Limited, *Edinburgh.*

Supplement to NATURE

No. 2944 APRIL 3, 1926

Our Bookshelf.

Man in the Past.

Les origines de l'humanité. Par Prof. René Verneau. (Bibliothèque générale illustrée, 1.) Pp. 80+59 planches. (Paris: F. Rieder et Cie, 1926.) 15 francs.

To summarise adequately and in popular language the present position of our knowledge of the origin and development of mankind in a compass of less than eighty pages of not very small type, is a feat which is possible only to a master of his subject with a gift of lucid exposition such as Prof. Verneau. In this little book the uninstructed reader will find all that is essential for a thorough understanding of the elements of his subject and the bearing upon it of the geological and palæontological evidence. Nor has the author hesitated to deal with matters on which the views of experts differ. Even such questions as the antiquity of the Calaveras skull and the theories of Ameghino on the antiquity of man in South America are briefly discussed and the points at issue set forth. On the question of Neanderthal man, Prof. Verneau gives a succinct and carefully argued summary of the evidence upon which is based his own view that Neanderthal man is not an aberrant and extinct form, but stands in the direct line of descent as evidenced by atavistic types such as the Australian. Prof. Verneau's exposition is greatly helped by a very full series of remarkably well produced illustrations which alone would make this little book a possession to be desired by any archæologist.

Prehistoric and Roman Wales. By Dr. R. E. M. Wheeler. Pp. 229. (Oxford: Clarendon Press; London: Oxford University Press, 1925.) 18*s.* net.

WALES is a country which presents many difficulties and many pitfalls to the student of prehistory. The evidence is often scanty and sometimes, when considered in relation to the succession of cultural periods elsewhere, entirely lacking; and both in its character and in its distribution it is frequently puzzling to interpret. In the present volume, Dr. Wheeler has essayed to weave a connected story out of this material and, within the limitations imposed by the nature of his data, he has been eminently successful. His views are sane and cautious, but at the same time inspired with an imagination which is kept under careful restraint by a keen appreciation of how far his facts are capable of carrying the proof of any suggested conclusions. As an example may be cited the skilful use of probable climatic and geographical conditions in explaining the character and distribution of the palæolithic implement in Wales, the emergence of the area as a meeting place of culture from east and west, and its final transformation into a true frontier province under the Empire. His word of caution in regard to the, perhaps, too exuberant plotting of prehistoric trade routes is timely as well as characteristic. Amid so much that is excellent, a special commendation of the valuable summary and analysis of our present knowledge of Roman Wales may not be out of place.

Mystery Cities: Exploration and Adventure in Lubaantun. By Thomas Gann. Pp. 252+32 plates. (London: Gerald Duckworth and Co., Ltd., 1925.) 21*s.* net.

DR. GANN is well known as an explorer in the realms of Central American archæology, and needs no introduction. Those who have read his "In an Unknown Land" can have no doubt of his ability to describe his adventures in pursuit of scientific data with a graphic power and a humour which endear him to the hearts of his readers, while giving a sufficient account of his results to make his book of permanent value as a record. He here describes his journey of the season 1924–25 in British Honduras, first to explore mounds at Xunantunich and afterwards to Lubaantun, where he joined Lady Brown and Mr. Mitchell-Hedges, his fellow-concessionaires, and continued the work of a preceding preliminary reconnaissance.

One of the results of the journey, as is well known, was the discovery of the remarkable amphitheatre which has no parallel in the whole area once occupied by the Maya. It provided seating accommodation for at least 5000 people "or at a pinch possibly 10,000," and measures approximately 350 feet from east to west by 300 feet from north to south, the greater part of the space being taken up by seating and standing accommodation for the spectators of whatever was taking place in the arena. There is a pathetic interest in turning from Dr. Gann's description of the monuments of the ancient Maya to his account of their degenerate descendants of to-day, to whom he does more than justice.

Aspects of Psychology.

(1) *Education as the Psychologist Sees It.* By Prof. W. B. Pillsbury. Pp. ix+342. (New York: The Macmillan Co., 1925.) 8*s.* 6*d.* net.

(2) *Old and New Viewpoints in Psychology.* By Prof. Knight Dunlap. Pp. 166. (London: Henry Kimpton, 1925.) 10*s.* 6*d.* net.

(1) PROF. PILLSBURY aims at presenting a concise summary of the problems of the teacher as they appear to the psychologist. The first part deals with the statistical side of psychological research and the nature of intelligence. Then follows an account of the general psychological processes and laws helpful to the teacher, namely, instinct, habit, attention, reasoning. A chapter is devoted to feeling and emotion in relation to discipline. At the end of each chapter is a list of questions.

To the teacher with a good psychological training the book is a useful synopsis of much scattered work, but to the beginner and to the general reader, to whom the writer also wishes to appeal, it may give the entirely illusory idea that much more is known than is actually the case. There is little indication of what is hypothesis and what is theory. The interpolation of physiological details—for example, the synaptic hypothesis, to explain associated acts—does not elucidate psychological occurrences. The account of correlation is of little value to any one who already knows it and inadequate as a first introduction. If it is necessary to introduce the Freudian theories at all, then more space should have been devoted to them; casual criticism, with no indication of the data for criticism, is out of place in an elementary book. The difference between suppression and repression is not made clear.

Although somewhat stereotyped, parts of the text are interesting. Its defects are largely due to its note form.

(2) Prof. Dunlap has brought together a number of papers given by him to various societies, and, as might be expected, they are of unequal value. The first chapter, on mental measurement, is the best, being a very able review of current work on the subject. The author gives an account of the work leading up to the present-day intelligence tests; he describes the aims and methods of the tests, discusses the claims legitimate and illegitimate of workers in this field, and issues a warning against the futility of many popular expositions.

The chapters on spiritualism and on the comic are somewhat sketchy accounts of a vast field. Dr. McDougall's theory of laughter published in this journal in 1903 might help to elucidate some of the problems of the latter. The chapter on present-day schools of psychology enables the author to tilt at all the more outstanding current systems. Doubtless the most ardent Freudian would agree with the author that to "repress effectively" is the greatest asset a human individual can have: the trouble lies in the adverb attached.

As lectures they must have been very stimulating; whether they merit book form is doubtful.

Art and the Unconscious: a Psychological Approach to a Problem of Philosophy. By John M. Thorburn. Pp. xii+242. (London: Kegan Paul and Co., Ltd., 1925.) 10*s.* 6*d.* net.

Mr. Thorburn has attempted to discover how far the problems of art and the sources of its inspiration may be restated in the light of contemporary theories of the unconscious. He begins by considering a domain where we are all artists, namely, the dream life, and goes on to relate this to the problems of the nature and origin of the imagination, art and the archaic, the function of symbolism, etc. The range of subjects discussed is wide, comprising literature, architecture, painting, and music.

The author has derived much inspiration from the writings of Freud and Jung, but he does not therefore make the mistake of neglecting conscious processes in his enthusiasm for the unconscious. The book is a contribution to the interpretation of art, to philosophy, and to the psychology of the imagination. The style is not easy and in places is decidedly laboured, due obviously to the difficulty of the conceptions.

Medical Science.

Arteriosclerosis: a Summary View. By the late Rt. Hon. Sir T. Clifford Allbutt. Pp. viii+108. (London: Macmillan and Co., Ltd., 1925.) 5*s.* net.

Intended for the busy practitioner, this summary of a larger work contains added material which makes the essay an admirable statement of the present state of knowledge of the subject. Sir Humphry Rolleston, who saw the little work through the press, reminds the reader of additions made by the author to the science and art of medicine. "Some of these are now so thoroughly incorporated in common knowledge and practice that our indebtedness in this respect is largely forgotten, such as the invention of the clinical thermometer now in use and the description of syphilitic disease of the cerebral arteries." His distinction between hyperpiesia, or high blood pressure of obscure origin, and the hyperpiesis of renal disease, which is in one sense the kernel of the essay, will also take its place in medicine surviving the elucidation of what is now obscure. For the light shed on the difficult problems of arterial disease and its consequences the volume will have many readers. It deserves a wider public for its amazing skill in the marshalling of hosts of facts and its delightful literary style.

Lister and his Achievement: being the First Lister Memorial Lecture delivered at the Royal College of Surgeons of England on May 14, 1925. By Sir Wm. Watson Cheyne. Pp. iv+136. (London: Longmans, Green and Co., 1925.) 7*s.* 6*d.* net.

The First Lister Memorial Lecture was a compression of a short history of Lister's work. Both are here printed together; the first occupies the opening thirty-eight pages of the volume and the second the remainder as an appendix. Without consideration of the necessity of such an arrangement if the lecture is to be given permanence in its original form, the plan is nevertheless not a perfect mode of presentation. At the same time no one who is genuinely interested in the development of surgery and in the life of its great English exponent would sacrifice any one of the glimpses which Sir Watson Cheyne has given of his great teacher. It may be said, however, that the earnest championship of the whole technique and nomenclature of Lord Lister's practice met with in these pages as against the newer 'improvements' is now receiving much more support than formerly from many surgeons, and we may still see a revival of *antiseptic* surgery.

Natural History.

(1) *The Monkeyfolk of South Africa.* By F. W. Fitzsimons. Second edition. Pp. xiv+172+48 plates. (London: Longmans, Green and Co., 1924.) 10*s.* 6*d.* net.

(2) *Chats on British Mammals: Ungulates, Carnivores, and Insectivores.* By Dr. Jas. J. Simpson. Pp. 122+4 plates. (London: The Sheldon Press; New York and Toronto: The Macmillan Co., 1924.) 2*s.* 6*d.* net.

(1) In his preface Mr. Fitzsimons says: "I am a strong advocate of books being written in simple language, because they are then easily comprehended

by learned men and women, as well as the most ignorant schoolboy or girl." That sentence may not be a model of tactful expression, but it shows consideration for the learned, and that, alas! is far from general. The author also says, very truly, that: "In the degree that a writer is able to interest the mind of the reader, so just in that degree will he succeed in impressing the cells of the grey matter of the brain. Unless the teacher succeed in arousing the intelligent interest of his pupil, he can make but little headway." There is, however, a right and a wrong way of doing this, and most certainly Mr. Fitzsimons has followed the latter. Apparently imagining it to be impossible to give a direct and at the same time an interesting account of the monkeys of South Africa and their habits, he has chosen to play the part of a talkative and most irritatingly well-informed monkey. Many a moralist, no doubt, has used such a device for the conveyance and gilding of his philosophic pills; but the naturalist should remember that he is dealing with lilies and refined gold.

(2) A glimpse of the right way to arouse and secure the "intelligent interest" of a pupil in his natural surroundings may be got from Dr. Simpson's "Chats on British Mammals," an early one of a series of little books containing the admirable "ten-minute" talks on natural history broadcast by the author from the Cardiff Station. M. A. C. H.

Animal Life in the Sea. By R. J. Daniel. Pp. 119+4 plates. (Liverpool: University Press of Liverpool, Ltd.; London: Hodder and Stoughton, Ltd., 1925.) 5*s.* 6*d.* net.

Mr. Daniel gives a popular account of marine creatures from microscopic plants to fishes and whales, finishing with descriptions and explanations of various legendary sea serpents. It is a well-planned book, simply written, and will serve admirably for a first step towards interesting untrained observers in all that is to be found in the sea, the habits of the animals living in it, and the various phenomena connected with them, besides simple discussions of physical and chemical conditions from the surface to the depth of the ocean. The larger sea animals are most to the fore—fishes, whales, and giant cuttles—the illustrations being culled from many sources, including some from ancient maps and old pictures of sea monsters. Deep-sea animals are given special prominence, and the short account of conditions and life in the ocean depths is perhaps the best part of the book. In the small space of 117 pages an amount of interesting information has been included that might well have made a larger volume.

Concerning the Habits of Insects. By F. Balfour-Browne. Pp. x+169+9 plates. (London: Cambridge University Press, 1925.) 6*s.* net.

This small volume is the aftermath of the Christmas lectures, intended for a juvenile audience, which the author delivered at the Royal Institution in 1924. Its aim is to stimulate an interest in insect life and induce others to make observations in the wide field before them. In the first chapter the author utilises his own favourite studies of water-beetles as an example of what insect collecting may lead to. It is true that most of the real investigators in entomology were at one time in their lives collectors. There are also a great many folk who remain real collectors without ever becoming real entomologists. It is hoped that Mr. Balfour-Browne's book may lead to some depletion of the ranks of the latter class and, if so, retard the extinction of some of the more rare local insects.

In Chapter 2 the author describes his own delightfully simple and effective methods of observing the behaviour of some of the commoner solitary bees and wasps. The succeeding three chapters are devoted to phases of the habits of caterpillars, dragonflies, and water-beetles. All these accounts are written in a pleasing freshness of style, and there is no mistaking that the author has observed personally most of what he writes about. The book concludes with remarks on the economic significance of insects especially in relation to the transmission of tropical diseases. This apologia, as we may call it, for entomology winds up with an allusion to the possibility of a livelihood now being earned by its pursuit, although Mr. Balfour-Browne deplores any one taking up the subject with that intention.

A. D. I.

Notes on the Birds of Cley, Norfolk. By the late H. N. Pashley. Pp. 138+2 plates. (London: H. F. and G. Witherby, 1925.) 7*s.* 6*d.* net.

The late Mr. Pashley had the good fortune to live for many years on a part of the Norfolk coast which is almost unrivalled in the British Isles as a locality for rare migrants, and as a practising and well-known taxidermist he had great numbers of interesting specimens through his hands, in addition to the birds which he saw or obtained himself. The greater part of his small book—now published just after his death at the age of eighty-one years—consists of extracts from his ornithological diaries covering a period of thirty-eight years: this is a rich mine of information. There follows a systematic list in which the chief facts are conveniently summarised for each species. There are also a few pages of more general reminiscences.

One of the most interesting points which emerges relates to the changes which have taken place within the period covered. As Mr. B. B. Riviere says in his foreword, "The Shore-Lark and Lapland Bunting, which in the sixties and eighties respectively were regarded as very great rarities, are now regular winter visitors to Cley, the former in considerable numbers. The Black-tailed Godwit, no specimen of which appears to have found its way into Pashley's shop until the year 1917, has since then occurred regularly in the neighbourhood as an autumn, and occasional spring, migrant; whilst the Sandwich Tern, a rare passer-by of the eighties, now breeds in hundreds, almost within sight of Mr. Pashley's windows." These are gratifying facts to set off against the depletion of our avifauna in so many other directions.

Zoological Handbooks.

Zoologisches Wörterbuch. Von Dr. Erwin Hirsch-Schweigger. (Veit's Sammlung Wissenschaftlicher Wörterbücher.) Pp. viii+628. (Berlin und Leipzig: Walter de Gruyter und Co., 1925). 26 gold marks.

This short zoological dictionary is intended as a 'first aid' for professional zoologists, teachers, students, and amateur naturalists, its object being to provide a means

of rapid orientation, without entering into minute details. The ground covered is not restricted to zoology in the narrow sense, but includes cytology, anatomy, genetics, and theoretical biology in general.

As regards systematic zoology, the higher subdivisions down to orders and the most typical families are well represented. Brief diagnoses of these are given, together with references to some of the genera and species. The value of these diagnoses and other definitions is enhanced by numerous cross-references. Some of the systematic groups are provided with index-numbers of the "Bibliotheca Zoologica," to which the reader is referred for further information. The geographical distribution of separate forms is indicated in a similar manner, the respective regions being arranged at the end of the book in tabular form. The classification adopted is also given at the end, side by side with that of the "Bibliotheca Zoologica." A useful feature of the dictionary is the accentuation of Latin and latinised words and the etymology of these and other foreign words, given in brackets.

In a book of this type it is perhaps inevitable that certain inaccuracies will occur. Thus the Aggregataria (or Aggregatidæ) are referred to the Gregarinida instead of to the Coccidia; the causative organism of tropical malaria is referred to as *Plasmodium præcox*, without mention of the name *P. falciparum*. The retention of Hartmann's artificial group Binucleata does not accord with the view of most protozoologists. The various members of the family Filariidæ, which actually belong to different genera, are all placed in one genus, Filaria. These minor defects do not detract from the general merit of the book, which may be recommended as a useful short guide to zoological nomenclature. C. A. Hoare.

Animal Classification and Distribution, a Précis Reference Book: for Students of Elementary Zoology at Secondary Schools, Colleges, and the Universities; being a Time-saving Synopsis with Provision for a Digest of Lecture Notes and Sketches. By Douglas M. Reid. (Griffin's Scientific Text-books.) Pp. xv + 51 (every other page blank). (London: Charles Griffin and Co., Ltd., 1925.) 6*s*. net.

The purpose of this volume is expressed in the opening lines of the preface: "Experience in teaching students of zoology has shown that many who are unfamiliar with the laws and principles of classification lose much time in searching various books to determine the position of some organism, . . . and to meet this need the present synopsis is provided." It must be said at once that the volume will require many emendations and additions if it is to enable the student to determine the position of the animals he sees or collects. A number of the small subdivisions containing relatively rare forms might well have been omitted and the space so obtained devoted to a fuller definition of the main groups. Many of the definitions contain loose statements which will lead to misunderstanding; *e.g.* "epithelium absent" is given as one of the characters of Nematoda (no doubt cœlomic epithelium was intended), and Gordius is said to be free living—a statement which takes little account of the life-history; the Zoantharia are defined as having a calcareous skeleton, but the example of the order correctly cited is Actinia, which has no skeleton. The author would do well to study page 9 and ask himself how the reader will know by inspection whether certain worms "have possessed chaetae," if in all Polychæta the "head end is fitted with tentacles"; if the posterior sucker of a leech is on the posterior segment, why the leeches alone among annelids are cited as exhibiting embryonic development; if Gephyrea are hermaphrodite (see Bonellia) and the mouth and anus are at the opposite ends of the body (see Sipunculus), and why the presence of a vascular system and nephridia are noted in Gephyrea but left unnoticed in Oligochæta and Polychæta, where they (especially the vascular system) are much more typical.

We do not feel able to recommend this volume as tending to a solution of the student's difficulties in classification.

Plant Morphology.

Monocotyledons: a Morphological Study. By Dr. Agnes Arber. (Cambridge Botanical Handbooks.) Pp. xv + 258. (Cambridge: At the University Press, 1925.) 21*s*. net.

Dr. Arber has produced a very clear, learned, and admirably illustrated treatise on the monocotyledons. To be properly appreciated it must be studied in detail, since it is a carefully reasoned morphological study dealing with the study of plant organs from the point of view of their internal structural features as well as of their external. Thus the root, the axis, the foliage leaf in its various forms as represented in the monocotyledons, and the prophyll, including phylloclades, are fully treated. The seedling and its interpretation is also discussed at length. In the chapter on the reproductive phase the floral peculiarities exhibited are described and details of the structure of the embryo sac and ovule are given.

This is followed by a discussion on taxonomy and a very interesting chapter on parallelism in evolution. The book concludes with a full bibliography and carefully prepared index.

Dr. Arber, though a disciple and fellow-worker of the late Miss Ethel Sargent, has largely followed her own ideas in writing this book and the result is a work full of fresh light on a fascinating problem—the meaning and interpretation, especially as regards their vegetative features, of the very diverse organisms which are grouped together in the phylum monocotyledons.

Many theories have been put forward to explain the relation of the monocotyledons to the dicotyledons, the most generally accepted being that the former have arisen from the latter. Dr. Arber, however, considers that the evidence, both from the living plants and the scanty fossil records, is not sufficient to warrant acceptance of such views. She would rather maintain that the great groups of flowering plants came independently into existence, and that their immense variety of form and structure at the present day is due to reduction, fusion and degeneration. Adaptation, she holds very strongly, affords no explanation of the characters which distinguish groups.

Both text and figures deserve the careful attention of botanists and students of evolution. The book is not only one for which the author deserves very high praise, but is also a production which reflects great credit on the Cambridge University Press.

An Introduction to Plant Anatomy. By Prof. Arthur J. Eames and Prof. Laurence H. MacDaniels. (McGraw-Hill Publications in the Agricultural and Botanical Sciences.) Pp. xv+364. (New York: McGraw-Hill Book Co., Inc.; London: McGraw-Hill Publishing Co., Ltd., 1925.) 17*s.* 6*d.* net.

It is rare, indeed, that one meets a book that needs little but commendation, yet such is the case in connexion with this detailed text-book of plant anatomy. Without embarking upon general theories, the authors are merely concerned with the descriptive morphology of vascular plants. Physiological and ecological aspects of morphology, and the practical applications of this subject, are indicated incidentally to the general treatment, while comparative morphology is used only when it may help to make clear structural complexity. Although the treatment of the subject is in no way causal, yet the developmental side of morphology is well to the fore in chapters on meristems, the primary and secondary plant bodies, and in the treatment of cambial activities.

The view-point from which the organisation of the vascular tissues is developed is that these are primarily laid down on a cylindrical plan, from which various subordinate types can be traced. The treatment of this subject is as thoroughly up-to-date as the rest of the book. Lists of recent references are given at the end of each chapter, while excellent illustrations abound, notably those of different types of wood, presented by the courtesy of the United States Forest Service. The result is a well-balanced book which can scarcely fail to be of value to any botanist who uses morphological data.

Geology.

(1) *Mineralogie.* Von Prof. Dr. R. Brauns. (Sammlung Göschen, Band 29.) Sechste verbesserte Auflage. Pp. 143. 1·25 gold marks.

(2) *Geschichte der Geologie.* Von Prof. Dr. K. Hummel. (Sammlung Göschen, Band 899.) Pp. 123. 1·25 gold marks.

(Berlin und Leipzig: Walter de Gruyter und Co., 1925.)

These are recent issues of this excellent series which has been employed in Great Britain for practice in reading scientific German. The first (1) is a miniature text-book of mineralogy quite sufficient to give a sound elementary knowledge of the subject. It will be all the more welcome in Britain that Naumann's notation of crystal faces is discarded and only those of Weiss and Miller are placed before the student. The second (2) is a remarkably full but concise description of the historical development of geological science in all its branches.

Gestaltungsgeschichte der Erde. Von Dr. Leopold Kohn. (Sammlung Bornträger, Band 7.) Pp. vii+200. (Berlin: Gebr. Bornträger, 1925.) 7·50 gold marks.

This is a readable but somewhat discursive account of the problems presented by the history of the earth. Special attention is given to the geosynclinal theory of mountain formation, which in one form or another has gained considerable support in recent years, though it has not obtained the approval of Prof. Heim. On this and other subjects the opinions of different authors are freely quoted. Altogether it is a stimulating book, and if it is somewhat inconclusive, that is largely to be attributed to the difficulties inherent in many of the questions with which it deals. A folder is included, giving a synopsis of the different stages in the earth's history.

Popular Astronomy.

A Popular Guide to the Heavens: a Series of Eighty-six Plates; with Explanatory Text and Index. By Sir Robert Stawell Ball. Fourth edition, completely revised and edited by the Rev. T. E. R. Phillips. Pp. xii + 84 + 86 plates + 13. (London: George Philip and Son, Ltd.; Liverpool: Philip, Son and Nephew, Ltd., 1925.) 15*s.* net.

After an interval of fifteen years since the publication of the third edition, this book now appears rehabilitated under Mr. Phillips's able revision. To the usual planetary diagrams, numerous lunar and stellar charts, drawings of planets and comets, a number of photographs have been added to represent the work of modern astronomical photography, together with a concise summary of such topics as methods of measuring the distances of the stars, the classification of stellar spectra, and new information on variable stars.

It is to be regretted, however, that sunspots—a source of interest to many people possessing small telescopes—are not represented by a short series of photographs, illustrating, for example, the growth of a typical stream of spots. The single plate portraying sunspots by direct photography is, we think, unwisely retained from the last edition to the exclusion of more recent and better photographs. The Stonyhurst charts might also have been mentioned as being very useful to the amateur.

It can be said with confidence that every one interested in astronomy, whether possessing a telescope or not, will be well equipped with this popular guide—a title which deservedly expresses its purpose in the fullest sense.

A Voyage in Space: a Course of Six Lectures "Adapted to a Juvenile Auditory" delivered at the Royal Institution at Xmas 1913. By Prof. H. H. Turner. Second edition, with an Addendum on Recent Discoveries. Pp. xvi+344. (London: The Sheldon Press; New York and Toronto: The Macmillan Co., 1925.) 7*s.* 6*d.* net.

The first edition of this book was published during the unsettled times of 1915. The publication of a second edition comes, therefore, as a welcome reminder of these excellent lectures, which being reproduced in print are made accessible to an increasing number of hearers beyond the limits of the lecture room. To those who have heard one of Prof. Turner's discourses on astronomy, the book will require no further introduction. To others, a hearty invitation may be given to share in the good things provided for the young people (and their seniors) at the Royal Institution. A glance at the numerous illustrations, averaging at least one to every three pages of text, will show the

original, simple, and often amusing manner in which the author characteristically presents his subject to his audience.

The first three lectures are concerned with the preparations for the journey: (1) The starting-point, our earth; (2) the length of our voyage and the start through the air; (3) journeying by telescope. The remaining lectures are devoted to the journey itself: (4) visit to the moon and planets; (5) visit to the sun; (6) visit to the stars. During the interval of ten years between the publication of the two editions, the great advances of astronomy call for the addendum. In forty pages it is only possible, as the author says, to give samples of these advances. Nevertheless, the reader is introduced to things appertaining to relativity, the study of the upper air, recent ideas on stellar evolution, and the measurement of the diameter of α Orionis.

Mathematics.

Nouveau traité de mathématiques générales. Par Prof. Eugène Fabry. Tome 2. Analyse: Intégrales, équations différentielles, dérivées partielles, courbure, séries trigonométriques; Mécanique: vecteurs, cinématique, statique, dynamique, résistance des matériaux; théorie des erreurs. Quatrième édition entièrement refondue. Pp. 276. (Paris: J. Hermann, 1925.) 40 francs.

Prof. Fabry's object in this volume is to give a working knowledge of elementary mathematical analysis, leading to some of its mechanical applications. In the first half, dealing with differentiation, integration, and differential equations, he sketches the more familiar processes of the calculus but generally omits any reference to the refinements which a pure mathematician now considers to be essential to the discussion. Thus the account of Fourier series covers six pages, in which it is shown how to evaluate the coefficients, and includes no mention of the validity of Fourier's expansion. Subject to such limitations, the section on analysis contains little that is actually wrong. In the compass of 120 pages the ground covered ranges from elementary calculus to partial differential equations and Stokes' theorem. A reader prepared to disregard the niceties of pure mathematics will often find that the brevity of Prof. Fabry's treatment adds interest to the topics discussed.

Passing to the second half of the book, the section on statics contains three pages about catenaries. Centres of gravity and moments of inertia are discussed more fully. In dynamics there are chapters dealing with the motion of a single particle and with that of a rigid body about an axis. The last two chapters are devoted to the resistance of materials and the theory of errors, and are followed by a collection of 276 formulæ.

Prof. Fabry's style is lucid throughout, and his treatment of the various subjects discussed is brief through his ignoration of mathematical subtleties, not through over-condensation. The book, now in its fourth edition, is of greater value to engineers using mathematics as a tool than to students: the latter will generally find the author's treatment to be inadequate. W. E. H. B.

Modern Physics.

The Spectroscopy of X-rays. By Prof. Manne Siegbahn. Translated with the author's additions by Prof. George A. Lindsay. Pp. xii + 287. (London: Oxford University Press, 1925.) 20*s.* net.

This is an excellent translation of Prof. Siegbahn's well-known book, and it will be widely appreciated. Prof. Siegbahn and his pupils have made the field of X-ray spectroscopy peculiarly their own, and no one is better qualified than the author to review the present position of the subject. The refinements in technique which he has introduced have led to a knowledge of X-ray spectra which approaches in accuracy that of optical spectra at no very recent date, and the imposing table at the end of the book giving the principal X-ray spectral lines is a revelation as to the extent of the field surveyed.

The book has been written throughout from the view-point of the experimental investigator. Discussions of the purely theoretical aspect have not been entered into, but just so much theory has been given as will illustrate the interest of the various experimental results. The matter has been most carefully and wisely chosen with this object in mind.

The subject naturally divides itself into two parts, dealing with technique and with the significance for atomic physics of X-ray spectra respectively. In the first part an account is given of the types of X-ray tube, of spectroscopic apparatus, and of sources of high-tension current. Here will be found many useful hints, tables of the properties of materials, and a mass of information collected and arranged. The second part describes the laws of excitation of the spectra, the *K*, *L*, *M*, and *N* series, absorption spectra, the systematic arrangement of the spectral lines and its interpretation. The last chapter gives an account of the methods, other than those of wave-length measurement, which provide a means of measuring the inner energy levels of the atom.

X-ray spectroscopy is making such rapid advances that any review of it will need constant revision. One feels very grateful to the author for having found time, in the midst of his investigations, to collect the information and present it in an attractive and convenient form. His book is an excellent introduction to the subject and review of the present state of knowledge, and is in a form which will make it possible to bring it up-to-date in future editions. Prof. G. H. Lindsay has worked in the author's laboratory, and his translation does full justice to the simple and readable style of the original book.

A Treatise on Electricity. By F. B. Pidduck. Second edition. Pp. xiv + 664. (Cambridge: At the University Press, 1925.) 21*s.* net.

The first edition of Mr. Pidduck's valuable treatise on electricity appeared in 1916, and the important advances made in the science during the past ten years have necessitated some changes in the present edition. In the earlier part of the book the most important alteration is to be found in the mathematical introduction, the vectorial methods and notation now employed resulting in considerable improvement in the subsequent mathematical analysis. The author, however, is on

his guard against abandoning Cartesian analysis for a complete symbolic calculus, and his treatment should appeal to the physicist.

In the later chapters modern work has been described in considerable detail, though the treatment of recent theories of magnetism is somewhat slight. The chapter on electric oscillations is of great interest, and we find here scientific accounts of the triode as generator, detector, and amplifier, and also a description of its use for the production of short waves having a wave-length of only 30 or 40 cm. In the chapter on electricity in gases we have an account of the nuclear theory of the atom, and the results of Aston on the composite nature of the chemical elements obtained by means of his mass spectrograph. A separate chapter has been assigned to Röntgen rays, in which is given a compact but readable summary of the diffraction of the rays by crystals and of the nature and origin of the X-ray spectra of the elements. The last chapter deals with the electrical theory of matter, including Bohr's theory of the origin of spectra, the experiments of Gerlach and Stern showing definite orientation of electron orbits in a magnetic field, and the theories of the Zeeman and the Stark effect. In its revised form this treatise should prove of great assistance to the student of advanced physics.

The Dynamical Theory of Sound. By Dr. Horace Lamb. Second edition. Pp. viii + 307. (London: Edward Arnold and Co., 1925.) 18*s.* net.

THE lucidity which characterises all Prof. Lamb's writings is exemplified in a marked degree in his treatise on the dynamical theory of sound. In this respect he follows in the footsteps of his master, Lord Rayleigh, to whom he acknowledges his indebtedness. For the second edition a thorough revision has been carried out, and a number of errors have been corrected. In its new form, the book should be of the greatest value to a student beginning the serious study of the subject. It is, however, to be regretted that the accounts given of recent applications are somewhat slight. Many readers would have welcomed more detailed descriptions of the hot-wire microphone, the methods employed in sound-ranging, and the problems of physiological acoustics.

Colloid Chemistry.

The Effects of Ions in Colloidal Systems. By Prof. Leonor Michaelis. Pp. 108. (Baltimore, Md.: Williams and Wilkins Co.; London: Baillière, Tindall and Cox, 1925.) 12*s.* 6*d.* net.

THE author of this volume, who is a professor of biochemistry in Japan, was invited to lecture in the United States during April and May 1924. The material of these lectures is now presented as a brief monograph. In the introductory lecture, a defence is made of the pursuit by a biochemist of a line of research in pure physical chemistry. Such a defence is scarcely necessary, since it is a well-known phenomenon that a biologist with a genius for work in physical science, having a different range of interests and of relevant data from the professional physicist or chemist, can often make a contribution of exceptional value to the progress of pure science.

In the present instance the subject selected has been "The Effects of Ions in Colloidal Systems," and in a series of eight short lectures the author has presented in a most effective manner some of the principal problems that are encountered in this field of work, although he does not find himself able, in every case, to offer a complete solution. His chief interest appears to consist in the detection and study of "electric double layers," but one of the most interesting lectures deals with the properties of charcoal as an absorbent. This familiar material, instead of being a typical absorbent, as is generally supposed, appears to be unique amongst inanimate systems, since "experience has shown that *any* substance dissolved in an excess of water is adsorbed by charcoal," which "possesses a prominent faculty for adsorbing . . . non-ionised electro-indifferent substances."

The author introduces the term "acidoid" to describe substances such as mastic which have the properties of insoluble acids, whilst insoluble amino-acids are described as "ampholytoids." Fortunately, he has not yet begun to describe silver iodide as an "electrolytoid" in order to emphasise the fact that it is almost insoluble in water, but this will doubtless follow in due course.

English readers will be interested in the book, but will regard its price as excessive.

Introduction à l'étude des colloïdes: état colloïdal et ses applications. Par Prof. W. Kopaczewski. Pp. vii + 226 + 2 planches. (Paris: Gauthier-Villars et Cie, 1925.) 16 francs.

THE first 64 pages of this small work profess to give the principal facts about the colloidal state, "all hypotheses and theories . . . being passed over in silence," while the remainder is divided into two parts, dealing with its industrial applications and with the colloidal state and life. This ratio of space, which is to be found in some other recent publications and appears to be becoming specific to the subject, seems a little difficult to justify; if it is granted, the author may be said to have done his work well. Although the industrial applications cover an immense field—cellulose and its esters, artificial silk, glue and gelatin, soil, beer, are among the sub-headings—he succeeds remarkably well, on the whole, in showing how the progress of colloid chemistry has thrown light on empirical procedure, or has led directly to the invention of new processes.

In the part devoted to the phenomena of life, inordinate space is given to the work of Leduc, which, fascinating as some of the experimental results are, can scarcely be considered seriously as throwing light on what goes on in organisms. The author is a medical man, and this explains the somewhat extended treatment of subjects for which the general reader is not prepared, like anaphylactic shock; whether a book of the present kind is the place for a somewhat surprising and emphatic condemnation of blood transfusion may also seem doubtful.

The book will no doubt give a number of readers the impression that 'there is something' in colloid chemistry, and may induce a few of them to seek something more than a mere bowing acquaintance with the discipline.

Chemical Analysis.

The Theory of Quantitative Analysis and its Practical Application. By Dr. Henry Bassett. (Twentieth-Century Chemistry Series.) Pp. viii + 308. (London: G. Routledge and Sons, Ltd., 1925.) 15*s.* net.

Dr. Bassett has produced a most interesting and valuable book. It is not a treatise on analysis; it is rather an exposition of modern ideas in physical chemistry, copiously illustrated by reference to detailed accounts of good analytical methods. For example, the chapter on the solubility product treats of various silver-halogen titration methods, and the determination of barium as sulphate. In connexion with co-ordination and complex ions, one finds a number of nickel-cobalt separations and the ammonium phosphomolybdate precipitation. Colloids, amphoteric compounds, electro-affinity, the composition of aqueous ammonia—such are a few of the other chapter headings.

The work is useful to the student and to the analyst alike. A careful perusal should help materially towards a knowledge of modern concepts of physical chemistry, while the criticism from a new point of view reveals the strength or weakness of the many analytical methods dealt with. A search for new methods should be assisted by an application of the principles set forth in the book, since in this way it may often be recognised at the outset that a suggested course of action is unsound and therefore not worth investigation.

The book is well produced, and very few typographical errors have been noticed. T. W. H.

Miscellaneous.

1825–1925: a Century of Stupendous Progress. By Joseph McCabe. Pp. viii + 168. (London: Watts and Co., 1925.) 5*s.* net.

Mr. McCabe presents in this very intriguing book a thesis involving two points: (*a*) "that there has been in the last one hundred years more progress in every respect than had ever been witnessed in five hundred years before, and (*b*) that this progress is due almost entirely to science." The author makes out a very strong case. Mr. McCabe is apparently moved to a defence of modern progress partly by the contributions of Bertrand Russell and Schiller in the "To-day and To-morrow" series issued by Messrs. Kegan Paul, Trench, Trubner and Co., Ltd., and partly by the persistence with which certain writers decry modern tendencies and belittle our times. Against such men the author expresses himself very vigorously. But after all this sort of cry has been common to all ages and civilisations.

However, whatever may be the promptings, Mr. McCabe has presented a very effective picture of life in 1825 at all angles in contrast with the conditions of to-day, and in the latter portion of his work he shows very forcibly the part science has played in this social and economic evolution. It may be argued that civilisation reached heights in the past in every way comparable with those of to-day, but there is much in the author's contention that a culture which did not reach or touch the common people cannot be counted as a general influence. It is from this point of view that Mr. McCabe's case derives its main strength. "From the world of the Middle Ages no reform could be expected. The five per cent. of Europe who could read and think were precisely those who profited most by the existing order of things; the ninety-five per cent., the mass of the workers, lived at so low an intellectual level that they hardly ever dreamed of changes." We feel confident that this stimulating book will find a ready public. I. B. H.

Meteorological Office: Air Ministry. British Rainfall, 1924. The Sixty-fourth Annual Volume of the British Rainfall Organisation. (M.O. 275.) Pp. xv + 266. (London: H.M. Stationery Office, 1925.) 15*s.* net.

This work maintains the same high order which has characterised its predecessors, although the superintendency of the British Rainfall Organisation has again changed hands, Mr. R. Corless now being responsible. In addition to the general table giving the rainfall of the individual observers at nearly 5000 stations, many details of considerable interest are given. Maps and tables show the distribution of rainfall in each month and for the year, and its relation to the average. Discussions are given of heavy falls in short periods and of the number of days with rain, as well as of spells of dry and wet weather during the year. Records are given of evaporation and percolation through the soil.

For the British Isles generally, 1924 was the wettest year since 1903, and at many stations it was the wettest year on record. For the whole area the rainfall was 17 per cent. in excess of the normal; in 1903 the excess was 27 per cent. A local downpour of 9·4 inches occurred on August 18 at Cannington, Somerset, of which at least 8 inches fell in 5 hours; this unprecedented rainfall is discussed at length in a special article by Dr. Glasspoole. Details are also given of the widespread deluge in the great thunderstorm of May 31, floods being general in western and northern districts.

In each month from April to October the rainfall was above the average, which is the longest sequence of wet months since before 1881.

Statistics are given showing the relative dryness or wetness of each month or year in the series 1881 to 1924 for England and Wales, Scotland and Ireland separately, and for the British Isles as a whole.

C. H.

Chambers's Encyclopædia: a Dictionary of Universal Knowledge. New edition. Edited by Dr. David Patrick and William Geddie. Vol. 7: Manchester to Pennywort. Pp. iv + 855. (London and Edinburgh: W. and R. Chambers, Ltd.; Philadelphia: J. B. Lippincott Co., 1926.) 20*s.* net.

Seven out of ten volumes of this useful encyclopædia have now appeared. The present volume bears evidence of revision and correction up to last year, and some of the articles have been completely rewritten since the earlier editions. It is no mean feat to compress such subjects as mining into seven pages, music into five, or Norway into less than six, but it appears to be done successfully in this work without sacrificing essentials and yet keeping the articles in a readable form. There are several new coloured maps.

Printed in Great Britain by R. & R. Clark, Limited, *Edinburgh.*

Supplement to NATURE

No. 2948 MAY 1, 1926

The Source of Stellar Energy.[1]

By Prof. A. S. EDDINGTON, F.R.S.

IT is generally agreed that the gravitational energy released by contraction is quite insufficient to provide the heat squandered by the stars in radiation. The Helmholtz-Kelvin hypothesis of contraction leads to an age of the sun, and therefore of the solar system, which is much too low. Revision of Kelvin's calculation in the light of modern results does not materially alter his figures; the present position is that the contraction theory gives an age of the sun 46 million years, or 19 million years if we measure from the time when its photospheric temperature reached 3000°. Moreover, these figures are rather too high, because they make no allowance for energy retained in the sun as energy of ionisation, which substantially reduces the amount left available for radiation.

Physical and geological evidence seems to be conclusive that the age of the earth—reckoned from a period which by no means goes back to its beginnings as a planet—is much greater. The age of the older rocks found from their uranium-lead ratio is generally put at 1200 million years; lower estimates have been urged by Prof. Joly, but none low enough to save the contraction hypothesis. An extension of the Kelvin time-scale is also demanded by the evolution of the earth-moon system. On the astronomical side there is the evidence of the Cepheid variables; if δ Cephei has no supply of energy other than contraction, we can calculate the rate at which its density must be increasing and the consequent change of period of its pulsations. This turns out to be much greater than the observations will admit, and it is found that at least in the Cepheid stage, evolution is proceeding at not more than one-hundredth of the rate given by the contraction hypothesis. This argument, although primarily referring to the pulsatory theory, should apply also to rival theories which admit that the light-period is intrinsic in the star whether it is a period of vibration or rotation.

We seem to require a time-scale which will allow at least 10^{10} years for the age of the sun; certainly we cannot abate our demands below 10^{9} years. It is necessary to look for a more prolific source of energy to maintain the heat of the sun and stars through this extended period. We can at once narrow down the field of search. *No source is of any avail unless it liberates heat in the deep interior of a star.* The crux of the problem is not merely the provision for surface radiation, but the maintenance of the star's internal heat which keeps the gravitating mass from collapsing. To keep the sun in its present condition of distension it is necessary to maintain within it a temperature-gradient climbing from 6000° at the surface to 40,000,000° at the centre; if the present gradient is not kept up the sun will contract and evolve prematurely. Clearly you cannot maintain a temperature-gradient by supplying heat at the bottom end. If this year the sun encountered a swarm of meteors which bombarded it with enough energy to furnish a year's supply of radiation, that would not add a year or even a day to the life of the sun; its internal readjustments would go on unaffected. All that would happen would be that the sun would give us twice the normal amount of radiation this year.

Since we cannot very well imagine an *extraneous* source of heat able to release itself at the centre of the star, the idea of a star picking up its energy as it goes along seems to be definitely ruled out. It follows that the star contains hidden within it the energy which has to last the rest of its life. But energy cannot be successfully hidden; it betrays itself because it has (or because it is) mass. Energy of 9×10^{20} ergs has a mass 1 gm., and this will count as part of the mass of the star determined by astronomical methods. Energy of $1{\cdot}8 \times 10^{54}$ ergs has a mass 2×10^{33} gm., which is the mass of the sun; consequently that is the sum total of the energy that the sun contains. How much of this is capable of being converted into radiation we do not know; but if it is all available, there is enough to maintain the sun's radiation at the present rate for 15 billion years. To put the argument in another form, the heat emitted by the sun each year has a mass of 120 billion tons; and if this loss of mass continued there would be no mass left at the end of 15 billion years.

SUBATOMIC ENERGY.

This store of energy is, with insignificant exception, energy of constitution of the atoms and electrons; that is to say, subatomic energy. Granting that the Kelvin

[1] Last of a course of three lectures delivered at King's College (University of London) on March 1.

time-scale is inadequate, granting that our argument against extraneous sources of energy is valid, granting that the accepted view of the conservation of mass and energy is not erroneous, the source must be subatomic energy, for everything else has been eliminated. Most of the store is energy inherent in the constitution of the electrons and protons and cannot be set free unless they are annihilated. We have to suppose that a proton and electron run together, their electric charges cancel, and nothing is left but a splash in the ether which spreads out as an electromagnetic wave carrying off the energy. The possibility of this occurrence has long been a favourite speculation; for my own part, I first encountered it in Larmor's "Aether and Matter" (1900), where a vivid picture is drawn of the creation of a proton and electron by cutting the ether round a tube and giving it a permanent twist, and it is discreetly hinted that the tube might one day slip back. Whilst this is one alternative, a small—but perhaps sufficient—part of the store can be released by a less drastic process, namely, the transmutation of the elements. When a helium atom is formed out of protons and electrons, 0·8 per cent. of the mass, and therefore 0·8 per cent. of the energy, disappears. If this evolution of the elements is occurring in the stars, the energy so released might be the source we are looking for.

The conclusion that an appreciable part of the energy of protons and electrons can be released without destroying them is due to Dr. Aston's researches with the mass-spectrograph in 1920. He proved that the deviations of the chemical atomic weights from whole numbers was generally due to the elements being mixtures of isotopes, and that the weights of individual atoms approximate very closely to whole numbers in terms of O = 16; but for the hydrogen atom the small but significant deviation was confirmed, the weight being 1·008 and not exactly 1. This shows that the proton when isolated as in hydrogen has mass 1·008, but when brought into close contiguity with electrons in the nuclei of helium or higher elements, it has a combining mass 1·000. The difference no doubt represents the ordinary decrease of electrostatic energy when positive and negative charges are brought near together; and by the usual electromagnetic laws the disappearing energy (and mass) is carried away as radiation. If then helium is being formed in the stars, a supply of radiant energy is being released possibly sufficient to maintain their heat; and although mass is being radiated away, the total number of protons and electrons remains undiminished. This hypothesis was rather favourably considered by Prof. J. Perrin and the writer in 1920, but subsequent consideration has at any rate not strengthened its probability.

The further steps of evolution of higher elements release much less energy proportionately, so that not more than about 1 per cent. of the total store can be released, and that only if the material consists initially of hydrogen. In most of the work on the radiative theory it has been unnecessary to assume any particular chemical constitution of the star, except for the one proviso that there is not an excessive proportion of hydrogen; hydrogen gives widely different results from all the other elements, so that, curiously enough, the isolated scrap of information which we possess as to the chemical composition of the stellar interior bears upon this important question. I do not think we can admit more than 10 per cent. of hydrogen even in the youngest stars; it would thus appear that the evolution of the elements is far advanced in the pre-stellar nebular stage. In that case not more than one-thousandth of the total subatomic energy is releasable by transmutation, and the life of the sun past and future is brought down to $1{\cdot}5 \times 10^{10}$ years—a period perhaps not inadequate, but leaving little to spare. If we want more than this we must accept the hypothesis of annihilation of protons and electrons. The question now being put to the stars is, which of the two alternatives—transmutation or annihilation of matter—is providing the main supply of stellar energy?

Until recently the problem of the source of stellar energy was only of importance in connexion with the time-scale, and there was no pressing need for a decision between scales of 10^{10} and 10^{13} years. In 1916, when I began the studies described in the two preceding lectures, a more intimate contact with the problem seemed imminent, since some assumption must be made as to the relative distribution of the source in different parts of the interior. This distribution could be calculated definitely according to the Kelvin theory; but that theory was already obsolescent and there was no interest in working out the problem on such a basis. Progress became possible when it was realised that, within reasonable limits, the distribution of the source had only a minor influence on the results, and the question could be relegated to the stage of second approximation which we were not yet ready to undertake. It was early in 1924 that the problem was raised acutely by the conclusion that the dwarf stars are still in the condition of a perfect gas, contrary to the then accepted theory of evolution. It became clear that any new theory of evolution must be closely bound up with the laws of subatomic energy.

The Problem of Evolution.

It is well known that there is a certain statistical locus—a curve on the magnitude-type diagram—towards which the stars tend to concentrate. It was a merit of the giant and dwarf theory of evolution that

it indicated this locus as the track of evolution of an average star. Any arbitary change in the rate of liberation of subatomic energy would cause the star to move to some other position on the track, and the laws of subatomic energy were therefore only concerned in determining the *rate of progress, i.e.* the time-scale. They did not determine the track. The new conclusion makes this explanation of the statistical locus untenable. An arbitrary change in the liberation of subatomic energy will make the dwarf stars move off the track; we have therefore to exclude such arbitrary changes; that is to say, we have to consider the laws governing the liberation of subatomic energy if we are to understand the statistical locus.

In particular, the close dependence which we have found between luminosity and mass excludes any evolution of faint stars from bright stars unless we can admit that the mass decreases considerably during the star's lifetime. Not only in the giant and dwarf theory, but also in the theory which preceded it, evolution from the bright stars of types B and A to the faint stars of type M along the dwarf series has been a fundamental assumption. To avoid a complete upheaval of these ideas, we must admit substantial decrease of mass, and therefore the annihilation of matter. From this point of view—the aspect which concerns astronomers most practically—the hypothesis of annihilation of matter is really the most conservative; that does not necessarily make it true, but it justifies us in discussing it very seriously.

It is possible that a star might change mass in other ways than by radiation, but these other changes are probably much smaller. With fair certainty we can set an upper limit to the amount of accretion by the stars from diffuse matter in space; this turns out to be much less than the loss by radiation. The escape of matter from the stars must also be much smaller. I calculate that the sun's chromosphere would have to move outwards continuously at 100 km. per sec. in order to carry away as much mass from the sun as escapes by radiation. Needless to say, such a material outflow would be detected by the Doppler effect. I think, therefore, that the rate of loss of mass by a star can be set equal to its radiation so that it is a known quantity (independent of our views of subatomic energy), and the only question is whether the lifetime is sufficient for this loss to be a determining factor in stellar evolution. If the lifetime continues until the loss exceeds 1 per cent., the protons and electrons must be disappearing.

I suppose that most physicists will regard the subject of subatomic energy as a field of airy speculation. That is not the way in which it presents itself to an astronomer. Once it is granted that a star is evolving much more slowly than on the contraction hypothesis, so that its outflow of energy is practically the amount liberated within it, the measurement of the output of subatomic energy is one of the commonest astronomical measurements—the measurement of the heat and light of a star. Naturally the astronomer is not content to go on with these measurements indefinitely without an attempt to arrange them in some sort of coherence, to find out how they correspond with the internal temperature and density or the age of the material. If the physicist had in his laboratory unknown sources of energy, the output of which he could measure and the physical conditions of which he could determine, he would not be so backward in speculating on the causes and laws of the phenomena. The astronomical study of subatomic energy is no whit less direct than this; and although our attempts to weave the observational results into order are as yet unsuccessful, the problem is no more speculative than any other induction from experiment.

Exhaustibility of the Source.

Let us now examine some of the difficulties in the observational data. Consider the following:

The sun liberates 2 *ergs per gm. per sec. against* 58 *ergs per gm. per sec. by Capella.*

The sun has 620 *times the density and* 3·7 *times the internal temperature of Capella.*

Surely if density and temperature have any effect at all on the liberation of subatomic energy they must stimulate it. Density in particular brings the ingredients for any process closer together. Yet the sun, with higher temperature and density, liberates less than Capella. I think the only answer is that the sun is getting worn out; that it has, in fact, moved on to the higher density and temperature in order to stimulate a failing supply. It is admittedly an older star. We have thus an important factor forced on us, namely, exhaustibility of the supply.

Now consider the two components of Capella: a single star divided into two parts, and in accordance with the mass-luminosity law the heavier component radiates and has radiated more ergs per gm. than the light component. Consequently it has used up more of its supply. Yet the more massive star, more exhausted, at lower density, and at lower temperature, still liberates more ergs per gm. than its companion.

It may be urged that if the fission occurred within the last 100,000 years the components have not yet reached the steady state; in that case it would not be fair to equate the release of subatomic energy to the observed radiation. But the case of Capella is typical of the spectroscopic binaries in general,[2] and these

[2] Except that in the dwarf binaries there is no appreciable difference in the internal temperatures of the two components.

are so numerous that they cannot all be of so recent a date. In most *eclipsing variables*, however, the faint component is the cooler, and its lower output of energy would thus be explicable. These are stars in which the two components are very close together—sometimes almost touching—and their formation is probably recent. *It is just those stars in which (owing to recent formation) exceptional behaviour would be pardonable which require no excuse.*

Jeans suggests that when fission occurred the heavier component would appropriate the central portion of the original star, where the heaviest elements containing the more active sources might be concentrated. To this there are two objections. First, so far as we can calculate, diffusion is unable to effect any appreciable separation of the light and heavy elements in the lifetime of a giant star. Secondly, the rotation of the star causes circulating currents which keep the material sufficiently stirred. This last conclusion rests on a theorem of Von Zeipel criticised by Jeans; but I am convinced that Von Zeipel is right. It is therefore probable that when a star divides, the initial constitution of the two components is identical.

With regard to the latter point, some doubt may exist as to the efficiency of the stirring, owing to the likelihood that the circulation will become stratified. I understand that in a viscous liquid the vorticity has a tendency to break up into layers, so that the star might be divided into two or three shells with thorough mixing in each shell and not much mixing between successive shells. But even so I do not think that the general mixing would cease altogether. The diffusion which it has to counteract is exceedingly slow, and it would take at least 10^{13} years for the heaviest and lightest elements to separate. The age of Capella when it divided could not be much more than 10^{11} years. Moreover, although the heavy elements would tend to sink to the centre in small stars, the tendency in massive stars like Capella appears to be opposite. According to physical theory, the heaviest atoms have the highest absorption coefficients and experience the greatest radiation pressure. The interaction of the gravitational and electrical fields with radiation pressure leads to curious results; so that in Capella the heaviest elements together with hydrogen and helium would flow towards the surface, the other light elements tending towards the centre.

The Main Series.

Turn now to stars on the 'Main Series' which stretches from types O and B down the old dwarf series to type M. By far the majority of the stars are on this series, so that presumably it corresponds to the major part of a star's life. The giant stage appears to be a temporary halt during which a very active, but soon exhausted, supply of energy is being tapped; the star then goes on to the Main Series, where it remains until its chief supply is exhausted. At this stage, if at all, the energy is being derived from annihilation of protons and electrons, for the star cannot move along the Main Series unless it undergoes substantial loss of mass. We might expect the stars to continue in this stage until the end, since it is difficult to see why the protons and electrons should ever grow tired of destroying one another; apparently, however, some more refractory material is present (or is evolved) in the star, so that in some stars at least a residuum remains unburnt, which passes on to the fiercer ordeal of the 'White Dwarf' stage.

In the Main Series we find a simplicity in the laws of subatomic energy which is perhaps more embarrassing than the previous complications. As H. N. Russell has pointed out, all the stars in this stage have practically the same internal temperature. I find the central temperature on the Main Series to be 40 million degrees; Russell puts the figure rather lower.

The close uniformity of internal temperature is beautifully shown in a diagram for a considerable number of individual stars published by Russell (Nature, August 8, 1925, vol. 116, p. 209). The following treatment may be considered supplementary to his. It is difficult to allow for the errors of observational data of individual stars and to know just how much stress should be laid on particular discordances. We propose therefore the converse problem:—Assuming a constant central temperature of 40,000,000° along the Main Series, we find the consequent relation between luminosity and spectral type and compare it with the relation indicated by the general stellar statistics.

Results for assumed Central Temperature 4×10^7.

Mass.	Bol. Mag.	Vis. Mag.	Eff. Temp.	Type.
0·182	11·94	14·5	2,550°	<Md
0·258	10·25	11·6	3,210	K9
0·512	7·26	7·6	4,540	K0
0·746	5·93	6·1	5,160	G4
1·00	4·47	4·5	6,290	F8
1·58	2·43	2·5	8,250	A8
2·56	0·52	0·9	10,520	A0
4·53	−1·38	−0·6	13,260	B7
11·46	−3·86	−2·4	17,460	B2
37·67	−6·44	−4·3	22,500	Oe
90·63	−8·12	−6	26,200	O

From the mass in the first column and the assumed central temperature we can deduce the bolometric magnitude and effective temperature by the radiative theory.[3] The reduction to visual magnitude is taken to correspond to the effective temperature. In the last column spectral types are assigned corresponding to the effective temperatures according to what I

[3] In the first three lines of the table a small correction has been applied to the predicted bolometric magnitudes in order to bring them closer to the empirical mass-luminosity curve. (This correction is derived from data independent of the present type-luminosity comparison.)

suppose to be the most generally accepted scale. Taking columns 3 and 5 of the above table, we obtain a magnitude-type relation which follows with great accuracy the central line of the Main Series as indicated by observational statistics. Without laying undue stress on the closeness of the accordance, we must conclude that the temperature in this phase of evolution is surprisingly steady.

Whether the star requires a supply of 680 ergs/gm. sec. like V Puppis, 2 ergs/gm. sec. like the sun, or 0·08 ergs/gm. sec. like Krueger 60, it has to rise to a temperature of about 40,000,000° to obtain it. Apparently at that critical temperature the supply is *ad libitum*. Can we suppose that energy issues freely from matter at 40,000,000° as steam issues from water at 100°? I think that physicists would be hard put to it to reconcile such extraordinary behaviour with any accepted principles, yet that is what the astronomical observations taken at face value seem to insist on.

Overstability.

Here we encounter another difficulty depending on 'overstability.' Imagine a vertical cylinder with a piston, the chamber containing hot gas. To increase the resemblance to a star we must suppose that heat is continually being admitted into the chamber and an equal amount leaks away through the walls. The piston will rest in stable equilibrium on its cushion of hot gas, and if slightly displaced will return to its equilibrium position after small oscillations. But suppose that the piston operates a valve which admits extra heat to the chamber when the piston is lowered and shuts off the heat supply when the piston is raised. Then (allowing for the leakage) the chamber gains heat at the time of compression and loses heat at the time of rarefaction—just like the cylinder of any heat engine—consequently a slight displacement of the piston will set the engine working and the piston will move up and down with increasing amplitude. I call this 'steam-engine' condition *overstability*: it is not instability (a tendency to move away from equilibrium), but a tendency to return towards equilibrium with too much impetus so that oscillations increase instead of dying out. Now it will be seen that if there is a critical temperature, the oscillations of a star work a valve just in this way: If the star is compressed it becomes hotter; a larger region is raised above the critical temperature and more subatomic energy is released. If it expands, the centre falls below the critical temperature and the heat supply stops. Consequently the star begins performing like a steam-engine. If the power of the engine is only slight, it may be unable to overcome dissipative forces and the star will remain stable; but at least in the faint stars, which normally keep only a small region at the centre above the critical temperature, overstability will result. We know of some stars—the Cepheid Variables—which, whether from this cause or some other, are overstable and consequently pulsate, but they are uncommon, and they are all giant stars or stars at the head of the Main Series; they are, in fact, just the wrong stars to suit the theory.

I have referred to this difficulty of overstability primarily as an argument against too readily accepting the idea of a critical temperature at 40,000,000°, but it is also a general difficulty. The channel between the Scylla of instability and the Charybdis of overstability turns out to be so narrow that it is difficult to devise any law of subatomic energy which will steer the star safely through it. Tentatively I am inclined to cut the knot by introducing yet another complication. I suppose that a change of temperature or density does not immediately change the rate of liberation of energy; there is a time lag of months or perhaps hundreds of years, so that short-period changes have no effect. This would happen if temperature and density controlled the rate of formation of self-destroying material which afterwards proceeded to liberate its energy spontaneously at a rate unaffected by temperature and density.[4]

It will be seen that we have already encountered a number of difficulties. I daresay that we can wriggle out of these somehow, but that kind of procedure is not very convincing. I think that a successful theory ought occasionally to predict right results at the first attempt and not invariably to guess wrong, afterwards making amends by introducing a new complication. It looks as though we have not yet the right clue in our hands for a general synthesis of the problem of subatomic energy, and we are not prepared to advocate one theory in preference to another. We shall, however, continue here to glean what facts we can from the astronomical observations.

Dependence on Temperature and Density.

By considering the stability of a star we can show that the rate of liberation of energy increases with temperature or density or with both. Let the rate of liberation of subatomic energy be E and the rate of radiation from the star be L. In a steady state $E=L$. Now suppose that E drops below L; the star contracts (as on the Kelvin hypothesis which postu-

[4] If the annihilation of matter were due to free electrons shooting at the protons in the nucleus and destroying them by direct hits, the rate would be proportional to $\rho T^{-\frac{1}{2}}$ (subject to a dependence on the chemical composition if the protons in some nuclei are better protected than in others). As this law seems to have no support from observation, we conclude that it is not the free electrons but the bound or the nuclear electrons which perform the task. Hence arises the idea of formation of elements with a *penchant* for self-destruction.

lates $E=0$). But it is generally agreed that L increases as the radius decreases, so that the deficit is made worse. Further contraction ensues, with further increase of L, and the star gradually collapses. To save the star we must suppose that the increase of temperature and density by the contraction causes an increase of E, so that E becomes greater than L and drives the star back to equilibrium. The threatened instability is not catastrophic, and the collapse would occupy a time comparable with the Kelvin time-scale; but of course we must provide against such a collapse since we reject the Kelvin time-scale.

In Jeans's theories the release of subatomic energy is supposed to be independent of the temperature and density (by analogy with ordinary radioactivity). This view is also taken by Nernst. I have felt constrained to reject it from the beginnings of the researches on radiative equilibrium, since it leaves no means by which E and L for the different stars can be brought to a balance. Prodigious changes of density are required to alter L by a factor of more than 3 or 4, and as stated in the last paragraph, the adjustment of L is most probably in the wrong direction. It seems essential that the adjustment should come about by changing E. It is true that theoretical physics opposes difficulties to the idea that stellar temperatures can appreciably affect subatomic processes; but they are difficulties which obviously must be surmounted. It has, for example, been objected that the temperature in the stars is not great enough for the transmutation of hydrogen into helium—so ruling out one possible source of energy. But helium exists, and it is not much use for the critic to urge that the stars are not hot enough for its formation unless he is prepared to show us a *hotter place*.

The assumption that E is independent of temperature and density gives a cast-iron rule into which there seems no hope of fitting the astronomical data. It requires that the energy per gram liberated and radiated by any star depends only on the age. What zero the age is to be reckoned from is not clear. In any case, study of coeval groups of stars such as the Pleiades, Hyades, Præsepe, etc., does not confirm this hypothesis.

Evidence of Decrease of Mass.

We now consider more particularly the theory that the mass of a star changes considerably during its evolution. As already explained, this requires the more drastic hypothesis of annihilation of electrons and protons, transmutation of the elements being unable to provide sufficient energy for the longer time-scale involved. There can be no evolution down the Main Series unless this change of mass is admitted; the star would presumably evolve rapidly until it reached the Main Series, remain unchanged for the greater part of its life, and then go on to the white dwarf stage. That means that evolution would cease to play a prominent part in astrophysics. The fact that the stars leaving the Main Series (white dwarfs) are generally of smaller mass than the stars approaching it (giants) is an argument in favour of considerable change of mass in this stage.

The statistics of giant stars also support this view. Assuming that the most diffuse condition is the earliest, the average mass of a star at or near birth can be found from the statistics of giant K and M stars. Determining the masses from the luminosities, we find that 90 per cent. of these young stars have masses between 2·4 and 5·5 × sun; whereas the average for the stars in general is less than that of the sun. This strongly suggests that most stars have lost a large part of their original mass. The result fits in well with the conclusion reached in the first lecture that the masses of the stars correspond to the critical range where radiation-pressure is gaining ascendancy. Taking the average of all the stars, say $\frac{1}{3}$ to 1 × sun, radiation-pressure is between 0·007 and 0·05 of the whole pressure—clearly too low a value. But we ought rather to take the initial masses before there was any wastage; the masses 2·4-5·5 × sun give the proportion of radiation-pressure 0·17-0·35, which is just the range likely to be effective.

For this reason I conclude that stars are not usually born with mass less than 2 × sun. It might be argued that we do not observe diffuse stars of smaller mass because they condense very rapidly. But why? They are not exhausting their store of energy so fast, and ought to evolve more slowly.

Coeval Stars in Clusters.

There is, however, an argument perhaps equally strong on the other side which we shall now try to explain. We first draw up a table showing the time taken for a star to evolve through a given range of mass or of luminosity. This can be done because $dM/dt = -L/c^2$, the mass of the outflowing radiation L ergs being L/c^2 gm. Since L can be expressed as a function of M by the mass-luminosity law, the equation can be integrated[5] to give M as a function of t.

Mass (Sun = 1).	Abs. Bolometric Mag.	Duration of Stage.
∞ to 35	< −5	·038 × 10¹² years
35 ,, 10	−5 to −2½	·065
10 ,, 3·7	−2½ ,, 0	·214
3·7 ,, 1·73	0 ,, 2½	·93
1·73 ,, 0·92	2½ ,, 5	5·21
0·92 ,, 0·53	5 ,, 7½	36·3
0·53 ,, 0·31	7½ ,, 10	281
0·31 ,, 0·18	10 ,, 12½	2190

[5] *Monthly Notices, Roy. Astr. Soc.*, **84**, p. 328.

The table applies primarily to the Main Series on which the internal temperature remains constant, but can also be used with sufficient approximation for the giant stars. We see that, however large the initial mass, there cannot be more than mass 2 left at the end of a billion years. Consequently, if a cluster contains stars of mass greater than 2, that is, brighter than about $+2^m$, the cluster cannot be more than a billion years old. But looking lower down the table we see that a billion years is quite insignificant for the evolution of the fainter stars; so that if the cluster also contains stars of magnitude 5^m to 7^m, these must have been born with practically the same mass and luminosity which they now possess. It is found that many clusters contain bright and faint stars together, and our argument shows that in this case the faint stars cannot have evolved appreciably. If we have to deny the evolution of dwarf stars in clusters, is there any point in assuming evolution of dwarf stars in general? In any case it looks as though we must abrogate the idea that the stars cannot be born with masses less than 2.

Yet, although the observations of clusters appear to contradict our conclusion, we take some courage from the fact that they do so rather half-heartedly. (It is such a novel experience to find Nature taking any notice of our predictions in regard to subatomic energy, that a half-hearted denial is a cause for elation.) I learn from Hertzsprung that moving clusters such as the Hyades, Pleiades, and Præsepe certainly do not contain anything like their full quota of faint dwarfs. They stop suddenly at about $+7^m$, with few or none fainter than this limit. There appears also to be evidence that in globular clusters the dwarfs are not nearly so numerous in comparison with the giants as in the galactic system generally. Perhaps, therefore, there may be something in our argument as to the difficulty of bright and faint stars existing together in coeval systems, though we clearly have not yet got it formulated quite aright.

In the galactic system, where it is presumed that we have to do with a mixture of stars of all ages, the number of stars in any stage should be proportional to the duration of the stage. Hence the figures in the last column of the table should be proportional to the number of stars between the corresponding limits of magnitude. This prediction, however, applies only to masses below 2; the numbers corresponding to the earlier part of the table must be greatly reduced, because most stars start from masses between 2 and 5. The luminosity distribution predicted in this way is fairly well confirmed by the observational statistics.

Another test which affords some slight support for the theory of evolution by loss of mass has been applied by Vogt. It is easily seen from the table that if two stars start with widely different masses, the ratio of the masses will approach equality as time goes on. Hence in double-star systems we should expect large mass-ratios only in the early stages of evolution, and the mass-ratio should progressively approach unity for the later spectral types. This appears to be satisfactorily confirmed.

It might perhaps have been hoped that the loss of mass, through its effect on the dynamics of double-star systems, would clear up some of the problems with regard to their separations and eccentricities hitherto unexplained. This has been investigated by Jeans and Smart; but the results are disappointing, and the new theory does not bring any illumination to the outstanding problems. Nor can I glean anything particularly favourable or unfavourable to the theory from the various other discussions which have appeared.

Compton Effect.

As illustrating the close connexion between the progress of pure physics and astronomy, we may note that the discovery of the Compton effect relieved what had been a real difficulty in regard to subatomic sources of stellar energy. By the quantum theory the radiation emitted in the formation of helium from hydrogen should be of wave-length 0·00041 Å.U., and in the annihilation of a proton and electron 0·000013 Å.U. By what mechanism can this high frequency radiation be transformed down to the ordinary forms of heat energy in a star? The usual absorption coefficients fall off as the cube of the wave-length, and the second of the above quanta would probably go right through the star—and to the end of the world—without finding anything to absorb it and turn it into utilisable heat. It would be scattered fairly often, because the coefficient of scattering by electrons, although decreasing for short wave-lengths, does not fall off so rapidly; but so long as it was thought that the wave-length was unaltered by scattering, that did not help to solve the difficulty. Now the theory of the Compton effect tells us that the wave-length is increased by 0·024 $(1-\cos\theta)$ Å.U. after scattering; so that, however short the original wave-length, the first appreciable scattering reduces the radiation to ordinary γ-ray status. Most of the energy passes into a recoil electron which flies off with enormous energy; and there is then no difficulty in seeing how the energy is frittered away into ordinary molecular heat.

Penetrating Radiation.

The question of the origin of the penetrating radiation found in the earth's atmosphere has considerable interest in connexion with subatomic energy. An

astronomical turn was given to the problem a few years ago by Kohlhörster's experiments, which claimed to show that the radiation was travelling downwards and, therefore, presumably coming from outside our atmosphere. He found also that the intensity depended on the altitude of the Milky Way, so that most radiation was received when the greatest extension of the stellar system was overhead. The altitude of the sun made no difference, showing that the sun was not the source. The penetrating power was evidently much greater than that of any known γ-rays, so that it seemed clear that the radiation could only come from some powerful subatomic source such as the transmutation of hydrogen or the annihilation of matter. Very recently Millikan has announced the results of an extensive and careful study of this radiation. He is strongly convinced that it comes from extra-terrestrial sources; and he finds that the penetrating power agrees with that of the quantum emitted in the formation of helium from hydrogen.

Being unfamiliar with the technical details and difficulties of the experiments, I cannot take sides either with Kohlhörster and Millikan or with their critics. In the earlier days it had seemed to me that the high penetrating power (which seems to be universally admitted) went far to settle the question. This indicated a concentration of energy such as could only result from drastic subatomic processes; and it was at any rate less sensational to suppose that these processes were occurring in the depths of space than to postulate them on our own planet. But I was somewhat shaken by C. T. R. Wilson's calculations as to 'run-away' electrons in thunderstorms. He showed that these could acquire sufficient energy to furnish radiation of this nature without involving subatomic processes. It would, however, be difficult to account for the downward flow of the radiation if it were originated by Wilson's electrons.

If physicists ultimately are satisfied as to the extra-terrestrial origin of the radiation, what bearing will it have on the problems studied here? The chief conclusion to be drawn from it is that the subatomic processes can occur at comparatively low temperature —less than 100,000°. All the really hot matter of the universe is securely tucked away behind walls sufficiently thick to stop and scatter the most penetrating radiation; it cannot be the source of the radiation reaching us. Our choice lies between the photospheric layers of the stars and the nebulous matter in space. The latter origin is the more probable. Unless the stars are more potent sources than the sun, the penetrating radiation from the stars will be to that from the sun roughly in the proportion of starlight to sunlight; the experiments show that no appreciable part comes from the sun, and *a fortiori* that from the stars should be negligible. The diffuse and dark nebulæ and the matter scattered through interstellar space may perhaps amount to a total mass as great as the whole mass of the stars; and, moreover, there is no screening, so that all the radiation originating from it is able to reach us.

If this is right we must draw another important conclusion—the subatomic processes can occur at extremely low density. Astronomically we welcome these conclusions. We are hard put to it to explain the occurrence of helium and other elements in the nebulæ and of rather advanced elements in the spectra of the earliest stars, unless there is a building up of the higher elements in the pre-stellar stage of low temperature and density. But the physicist may well shake his head over the problem. How are the protons and electrons to meet and cancel one another in a medium so rare that the free path lasts for years? How are 4 protons and 2 electrons to assemble together and create a helium nucleus? It is perhaps a comfort that this last occurrence is so improbable under any conditions of density and temperature that we can postulate it in the nebulæ—on the principle that we may as well be hung for a sheep as a lamb. We recall also that these conclusions are in keeping with the observational fact (so difficult to reconcile with theory) that in general it is the diffuse low-temperature stars which liberate subatomic energy most prolifically.

I should have liked to close this course by leading up to some great climax. But perhaps it is more in accordance with the conditions of scientific progress that it should fizzle out, ending with a glimpse of the obscurity which marks the frontiers of present knowledge. I do not apologise for the lameness of my conclusion, for it is not a conclusion. I wish I could feel confident that it is even a beginning.

Printed in Great Britain by R. & R. Clark, Limited, *Edinburgh.*

Supplement to NATURE

No. 2952 MAY 29, 1926

Electrons, Atoms and Molecules.[1]

By Prof. T. M. Lowry, F.R.S.

ANY one who is familiar with the state of chemistry before and after the War must recognise that, whilst chemical practice and chemical beliefs have undergone very little alteration, the foundation underlying these beliefs has been altered profoundly by recent physical discoveries. In particular, although chemists still believe in Dalton's atoms and in the molecules of Avogadro, they have been compelled to accept an entirely different picture of the structure of the atom, and to adopt a new and revolutionary conception of the nature of the forces which bind the atoms together into molecules. Whilst, therefore, chemical research still proceeds along familiar paths, and is expressed by means of familiar terms and symbols, physical research has given us a new outlook; and, since what a man does is ultimately determined by what he believes, it is certain that chemical practice as well as chemical theory must be influenced profoundly by the new ideas that have been given to us by our physical colleagues. The object of this discourse is to indicate some of the aspects of pre-War chemistry which have been transformed by the impact of post-War physics.

Molecular Dimensions.

The principal contribution of the physicist to our knowledge of molecules has been a numerical one. He has taught us how to count, to weigh, and to measure individual molecules, and, in the person of Sir William Bragg, he has provided us with a convenient system of units in which to express these quantities. This system is based upon Ångström's unit of length, 10^{-8} cm., which has long been used in order to express the wave-lengths of light of different colours. Bragg has, therefore, proposed [2] to measure areas and volumes in 10^{-16} sq. cm. and 10^{-24} c.c.; and although it is scarcely possible to picture the process of filling with water a vessel with a capacity of only 10^{-24} c.c., it is, nevertheless, an obvious step to make the unit of mass correspond with the unit of volume, as 10^{-24} gram.

Having got a suitable system of units, we can use them in order to express atomic and molecular dimensions. The fundamental constant in this investigation is the *Avogadro number*, which tells us the actual number of atoms in the gram-atom of any element, or of molecules in the gram-molecule of any element or compound. Unlike Loschmidt's number (which tells us how many molecules there are in 1 c.c. of a gas at normal temperature and pressure), this is a universal constant, since it is not influenced by deviations from the ideal gas laws. During the past twenty years, more than a score of attempts have been made to determine the numerical value of this constant, by the most diverse methods; but I need only quote the number finally deduced by Millikan in 1917 from a study of the movement of a rain of electrified oil-drops. This curiously indirect method has given surprisingly accurate results; indeed, it is said that the number of molecules in a gram-molecule of a pure substance is known with about the same degree of accuracy as the total population recorded in the census of a big city such as Chicago. In conformity with our scheme, Millikan's value of the Avogadro constant can be expressed most conveniently in powers of eight as $N = 0{\cdot}6062 \times 10^{24}$.

By taking the reciprocal of this number we can deduce at once that *the weight of an individual atom or molecule in Ångström units is* 1·65 *times its atomic or molecular weight*. For example, the mass of an atom of hydrogen is $1{\cdot}65 \times 1{\cdot}0075 = 1{\cdot}66$ Å.U.; and the mass of a molecule of oxygen is $1{\cdot}65 \times 32 = 52{\cdot}8$ Å.U. From these data it would be easy to calculate the linear dimensions of the molecule if we could assume that it was spherical or cubical; but, although the early experiments of Devaux supported this view, more exact measurements have proved that the dimensions of the molecule are not equal in different directions. The molecule has, in fact, a definite shape, now open to experimental investigation, which must be taken into account in calculating its dimensions. Let me indicate three physical methods used for this purpose.

(*a*) *Viscosity of Gases.*—According to the kinetic theory of gases, the viscosity of a gas is a measure of the sectional area of the molecules. This was one of the earliest methods used to calculate molecular dimensions, and (unlike the two following methods)

[1] Compiled from lectures delivered at the Birkbeck College, London, on Jan. 25, and at Bristol on Feb. 12, 1926.
[2] *Proc. Phys. Soc.*, 1921, **34**, p. 35.

it is independent of a knowledge of the Avogadro constant. It has been developed in recent years by Prof. Rankine, who has deduced for the *collision-areas* of various gases values such as the following :

TABLE I.—COLLISION-AREAS OF GASES IN ÅNGSTRÖM UNITS.[3]

CH_4 = 7·72	NH_3 = 6·40	OH_2 = ?	HF = ?	Ne = 4·17
SiH_4 = ?	PH_3 = 9·11	SH_2 = 7·73	HCl = 6·76	A = 6·48
	AsH_3 = 9·85	SeH_2 = ?	HBr = 7·63	Kr = 7·57
	SbH_3 = ?	TeH_2 = ?	HI = 9·26	X = 9·15

These numbers, however, do not lead directly to a knowledge of the linear dimensions of the molecules, since they merely give the average area of the molecule as viewed from every possible aspect.

(*b*) *Monomolecular Films.*—Much more detailed information is given by a study of thin films of oil on the surface of water. So long ago as 1899,[4] Lord Rayleigh explained the fact that a definite concentration of oil was required in order to diminish the surface tension of water by supposing that it was necessary to cover the water with a film of oil one molecule thick, before any effect could be produced. Since the quantity required corresponded with a film of a thickness of about 10 Å.U., he concluded that this was the approximate diameter of the molecules.

When the Avogadro number was known it was possible to compare the *thickness* of the monomolecular film with the *area* occupied by the individual molecules, and thus to get some idea of their shape. Devaux, who first made this comparison in 1904,[5] was unfortunate in that the triolein with which he worked gave a monomolecular film with a thickness of 11 Å.U., as compared with a calculated molecular diameter of 11·3 Å.U. He therefore concluded that the molecules were roughly spherical in shape, as Rayleigh had postulated ; and it was left to Langmuir in 1917[6] to discover that the dimensions of the molecule are in fact widely different in different directions. Thus in Table II. the molecular

TABLE II.—CROSS-SECTIONS AND LENGTHS OF MOLECULES.

Substance.	Formula.	Area per Molecule.	Width.	Length.	Length per Carbon Atom.
Palmitic acid .	$C_{15}H_{31}COOH$	21 Å.U.	4·6 Å.U.	24·0 A.U.	1·5 Å.U.
Stearic acid .	$C_{17}H_{35}COOH$	22	4·7	25·0	1·39
Cerotic acid .	$C_{25}H_{51}COOH$	25	5·0	31·0	1·20
Tristearin .	$(C_{18}H_{35}O_2)_3C_3H_5$	66	8·1	25·0	1·32
Myricyl alcohol	$C_{30}H_{61}OH$	27	5·2	41·0	1·37

area was deduced directly by dividing the total area of the film in Å.U. by the number of molecules which it contained ; the width is merely the square-root of this area ; but the length was calculated on the assumption that the density of the film is equal to that of the oil in bulk, and that the length of the molecule is equal to the thickness of the film.

To Langmuir, then, belongs the credit of discovering that, whilst the sectional area of the molecule of a saturated fatty acid or alcohol is approximately constant, corresponding with a square with a side of about 5 Å.U.,[7] the length of the chain may extend to more than 40 Å.U. As a result of these observations, Langmuir was also able to assert that the individual molecules in the film were oriented, with the acid radical immersed in the water and the hydrocarbon chain projecting outwards towards the air. The spreading of the oil into a monomolecular film could therefore be attributed to the striving of the 'hydrophilous' or thirsty 'heads' of the molecules to secure access to the water, and of the 'hydrophobic' or oily tails to escape drowning.

Most of the applications of Langmuir's conception are physical in character, as in the case of the lowering of the surface tension of water by a film of oil. Harker, however, has recently put forward a case[8] in which the chemical properties of a compound appear to be determined by the orientation of the molecules in the surface of the liquid. Thus, he found that benzyl chloride could not be hydrolysed by dry steam, but was rapidly hydrolysed whenever there was an opportunity for liquid water to condense. This result can be explained most easily by supposing that the steam could not secure access to the active 'heads' of the molecules, since these would normally be directed towards the interior of the liquid, but that liquid water can reverse this orientation, and thus bring the chlorine into a position in which it can be attacked.

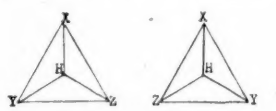
(*c*) *X-ray Analysis.*—The third method depends on investigating the distance between the mass-centres of atoms or molecules by means of X-rays. This is a reciprocal process, since our knowledge of the wave-lengths of X-rays does not yet rest on direct measurements of length, but has been deduced indirectly from the distance between the atoms of sodium and chlorine in a crystal of rock-salt, as calculated with the help of Avogadro's constant. Thus, since one gram-molecule of salt occupies 27 c.c., it is clear that the total number of atoms of sodium and chlorine in 1 c.c. of salt is $2/27 \times 0{\cdot}6062 \times 10^{24} = 0{\cdot}0452 \times 10^{24}$; but, before we can calculate the distance between the centres of these atoms, we must know how they are arranged in the crystal. A preliminary survey by means of X-rays shows that the atoms of sodium and chlorine occupy alternate points in a simple cubic lattice ; we can, therefore, allot to each atom a cubic cell with a volume

[3] *Trans. Faraday Soc.*, 1922, **17**, 720.
[4] *Phil. Mag.*, 1899, **48**, 331.
[5] *Proc. Soc. Phys. Bordeaux*, April 1904; compare Smithsonian Inst. Report, 1913, 261.
[6] *J. Amer. Chem. Soc.*, 1917, **39**, 1848.
[7] The more exact measurements of Adam (*Proc. R.S.*, 1922, A, **101**, 452, 516 *et seq.*) have shown that the sectional area of the hydrocarbon chain is 21·0 Å.U., but that the 'head' of the molecule occupies an area of 21·7 Å.U. in the alcohols, and of 25·1 Å.U. in the fatty acids.
[8] *J.C.S.*, 1924, **125**, 500.

of $22{\cdot}1 \times 10^{-24}$ c.c. (the reciprocal of the preceding number); and by taking the cube root of this number we can deduce the distance between the atoms as 2·81 Å.U. After having determined this fundamental distance, we can use a crystal of rock-salt[9] as a diffraction grating in order to determine the wave-lengths of the X-rays emitted by the elements, and we can then use these wave-lengths in order to determine the distance between the atoms or molecules in other crystals. In this way it has been shown, for example, that the distance between the carbon-atoms in a diamond is 1·52 Å.U., and that the same 'atomic diameter' appears incessantly in other carbon-compounds. This diameter, indeed, is one of the most constant of the numerical properties of the element, and is the obvious basis for a modern space-chemistry of carbon compounds.

Stereochemistry.

In addition to providing information as to the distance between atoms and molecules, X-ray analysis has made important contributions to our knowledge of molecular configuration or 'chemistry in space.' The first of the new chemical space-models was developed in 1874 by le Bel and Van 't Hoff, in order to account for the limited number of isomers which can be prepared of carbon compounds of various types. Thus since isomerism in derivatives of methane first appears in compounds of the type CHXYZ, these authors were led independently to postulate a *tetrahedral* configuration of the four univalent radicals around a central atom of carbon, in place of the *square* configuration of the common two-dimensional formulæ. The two opposite ways in which the four different radicals in these 'asymmetric' compounds can be arranged in space about the central atom of carbon could then be represented by alternative symbols, corresponding with the two known isomers, as follows:

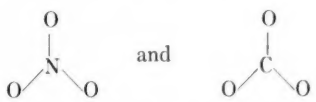


The new three-dimensional formulæ were confirmed by the experiments which led to the enunciation of von Baeyer's *Strain theory*, since it was found that a 5-atom ring with angles of 108° is more easily formed than a 4-atom ring with angles of 90°, as would be expected if the normal angle between the bonds is the characteristic tetrahedral angle, 109½°, of the solid model, instead of the right-angle of the planar formulæ.

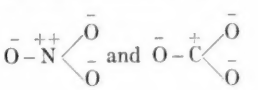
[9] Our exact knowledge of the wave-length of X-rays was formerly limited in the upward direction to about 15 Å.U., because no suitable crystals of larger molecular dimensions were available to provide a grating for their investigation. Thoraeus and Siegbahn (*Ark. f. Mat. Astron. och Fysik*, Stockholm, 1925, **19**, 12), however, have recently measured wave-lengths up to 21 Å.U. by using as a grating a crystal of palmitic acid for which $2d = 71{\cdot}19$ Å.U.

This chemical evidence has now been confirmed by direct physical measurements. In particular, X-ray analysis has proved that the diamond is built from tetrahedrally-oriented atoms, and in such a simple manner that a child of five, if provided with a supply of rods and balls with properly adjusted sockets, could not build the model differently. A similar tetrahedral configuration of four beryllium atoms around a central atom of oxygen, and conversely of four oxygen atoms around a central atom of beryllium, has been found in basic beryllium acetate,[10] $OBe_4(O_2CMe)_6$; and the X-ray analysis of ice[11] shows four hydrogen atoms arranged in the same tetrahedral pattern about each atom of oxygen. A tetrahedral arrangement of four oxygen atoms around a central atom of sulphur has also been found in barium sulphate.[12]

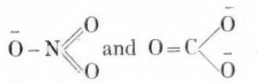
Moreover, in addition to confirming and extending the scope of Van 't Hoff's tetrahedral configuration, X-ray analysis has also indicated the existence of other configurations. Thus in ice, every atom of hydrogen is placed at the centre of a line joining two oxygen atoms, thus giving rise to a *linear* configuration, —O—H—O—. Again, in sodium nitrate, and in calcite and aragonite, we find a *triangular* configuration of three oxygen atoms about a central coplanar atom of nitrogen or of carbon, the three oxygen atoms being ranged symmetrically about a trigonal axis, as in the schemes



In order to preserve this trigonal symmetry, the ions in the crystal have been formulated[13] as



instead of



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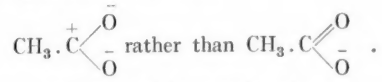
This planar configuration has been observed also in the acetate groups of basic beryllium acetate, where the two oxygen atoms are arranged symmetrically about a digonal axis, *e.g.*, as in



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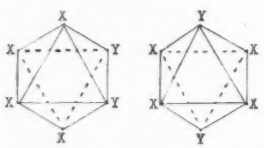
Moreover, graphite, which was thought at one time

[10] Bragg and Morgan, *Proc. R.S.*, 1923, A, **104**, 437.
[11] Bragg, *Proc. Phys. Soc.*, 1922, **34**, 98.
[12] James and Wood, Manchester Memoirs, 1924–5, **69**, No. 5.
[13] *Trans. Faraday Soc.*, 1923, **18**, 285. In these symmetrical formulæ the central atom carries only a sextet of electrons: this condition is, therefore, probably unstable except in the crystals, where the anion is surrounded symmetrically by six oppositely charged cations.

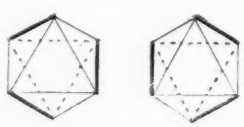
to contain the same zigzag network of atoms that can be recognised in successive layers of a diamond, is now reported to contain a *flat* network of hexagons.[14] Since graphite has the structure of an aromatic hydrocarbon, and actually gives rise to mellitic acid $C_6(CO_2H)_6$ on oxidation, it is difficult to resist the conclusion that the characteristic form of the benzene ring may after all be the traditional 2-dimensional hexagon rather than a zigzag hexagon in three dimensions.

Configuration of Co-ordination Compounds.

As in the case of carbon, the X-ray analysis of co-ordination compounds has proved the correctness of a configuration which had been deduced previously by purely chemical methods. Many years ago Werner concluded that the six chlorine atoms of potassium platinichloride, $K_2[PtCl_6]$, are all grouped round a central atom of platinum, instead of forming two groups, as in the formula, $2KCl, PtCl_4$. By studying the number of isomers that could be prepared of co-ordination compounds of different types, he was able to assign an *octahedral* configuration to the six co-ordinated radicals. Thus the existence of two isomers of the type MX_4Y_2 follows at once from the fact that substituents may occupy adjacent or opposite apices of the octahedron.



Werner's theory was finally established by the discovery, in compounds such as the cobalti-oxalates, $K_3[Co(C_2O_4)_3]$, of a new type of optical activity, which no one else had even suspected to be possible. This optical activity can, however, be explained immediately by means of an octahedral model, as in the following projection,[15] where the thick lines indicate the positions of the three oxalate groups.



X-ray analysis has now revealed, by direct mensuration, an octahedral configuration of the six halogen atoms in $K_2[SnCl_6]$, $(NH_4)_2[SnCl_6]$, $(NH_4)_2[PtCl_6]$, $K_2[PtCl_6]$ and $(NH_4)_2[SiF_6]$, as well as of the six atoms of chlorine which surround each atom of sodium in a crystal of rock salt. Even more important is the proof that the six molecules of ammonia in the ammoniate $NiCl_2, 6NH_3$, are arranged in an octahedral pattern about the central atom of nickel,[16] since this confirms in the minutest detail the formulation of the compound as an *ammine* of the type $[Ni . 6NH_3]Cl_2$. Modern physics has thus provided a new and very secure foundation for an important item of belief, which has only recently been added to the chemists' creed.

Ionisation.

During a period of forty years, physical chemists have asserted that when an electrolyte is dissolved in water it is partially dissociated into free ions

$$NaCl \rightleftharpoons \overset{+}{Na} + \overset{-}{Cl}.$$

No adequate basis was provided for this "nonsensical hypothesis" (as Prof. Armstrong described it in a letter to Nature of November 26, 1896), "which asserts that hydrogen chloride and a few other compounds are so loosely strung together that they fall to pieces when dissolved in water: out of sheer fright it would seem, as no valid motive is suggested for such self-sacrifice." An excuse for this strange conduct was afterwards found in the affinity of the ions for water; but at the time the 'dissociationists' preferred to use the 'blessed word' *allotropy*[17] as a mask to conceal the difficulty of explaining the supposed indifference towards one another of oppositely charged atoms of sodium and chlorine, as contrasted with the violent interaction of metallic sodium with gaseous chlorine and the still more violent interaction that might be expected between the atoms of the two elements. The more concrete suggestion that "the atoms of the dissolving electrolyte evolve heat by combining with their electric charges,"[18] was laughed out of court as being absurdly opposed to sound physical doctrine, since experience had shown that energy was always used up in the electrification of matter, and that the energy required to impart a given charge to a spherical conductor was inversely proportional to its diameter, and must therefore be enormous in the case of single atoms.

Modern physics has turned this problem inside out, since it is the molecules, and not the ions, of a salt of which the existence is now questioned. Thus, according to current views, the metals are so ready to lose electrons and the non-metals to gain them, that the ions of a salt are more stable than the corresponding neutral atoms. It is therefore impossible for these ions to neutralise their opposite electrical charges in

[14] Bernal, *Proc. R.S.*, 1924, A, **106**, 749; Hull, *Phys. Rev.*, 1917, **10**, 661; Debye and Scherrer, *Phys. Zeitschr.*, 1917, **18**, 291.

[15] *Chemistry and Industry*, March 9, 1923, **42**, 224. This projection, which I suggested in 1923 as a substitute for that used by Werner, has the same hexagonal outline as the diagram commonly used to represent the derivatives of benzene. It has the advantage of showing clearly that the metallic atom in the cobalti-oxalates is dissymmetric, but not asymmetric, since the model has one axis of 3-fold symmetry and three axes of 2-fold symmetry.

[16] Wyckoff, *J.A.C.S.*, 1922, **44**, 1239.

[17] Ostwald, "B.A. Report," 1890, 333.

[18] Nature, Dec. 17, 1895, p. 151.

order to produce a neutral molecule of salt. The utmost that can be done is for two oppositely charged ions to cling together to form a loose doublet, which is always free to interchange ions with another similar doublet. This state of affairs prevails no doubt in the vapour, as well as in concentrated aqueous solutions. Dilution with water then produces a real 'electrolytic dissociation,' $\overset{+}{\mathrm{Na}}\overset{-}{\mathrm{Cl}} \rightleftharpoons \overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{Cl}}$, in which ready-formed ions are merely separated from one another, *e.g.* by the intrusion of molecules of the solvent, instead of being created *de novo* from neutral molecules.

This revolutionary doctrine is supported by the X-ray analysis of salt, which reveals the fact that every atom of sodium is surrounded symmetrically by six atoms of chlorine and conversely. Since there is no difference in the distances which separate a given atom of sodium from six neighbouring atoms of chlorine, there is no experimental justification for asserting that any one of these atoms is combined selectively with the central atom of sodium to form a molecule. On the other hand, crystallographers state that the crystal of salt is not holohedral like Bragg's model, but hemihedral, so that there may be some factor in the structure of the crystal which is not revealed by examination with X-rays.

Physical chemists have not been slow in following up the lead thus given, and have been able to prove that many of the properties of dilute salt solutions can be explained by the *electrostriction* between oppositely charged ions, distributed just as in a crystal of rock-salt, but in a more irregular manner and at a greater average distance from one another.

Chemical Affinity.

The combination of unlike elements, *e.g.* of metals with non-metals, which is so important in inorganic chemistry, was explained some twenty years ago by J. J. Thomson [19] as due to a process of *electron-transfer*, *e.g.* to the transfer of an electron from an atom of sodium to an atom of chlorine. The chemical affinity between sodium and chlorine was then attributed to the electrostatic attraction between oppositely charged atoms of the two elements.

In its most elementary form the new electrochemical theory was not very much in advance of that put forward a century before by Berzelius, since it gave no precise explanation to show why an atom of sodium should be ready to part with an electron or an atom of chlorine to accept one. Even in the hands of Ramsay,[20] therefore, it did not render any important help to chemists in solving the difficult problem of the nature of chemical affinity. When, however, we had not only learnt from J. J. Thomson of the existence of the electron, and of its presence as a common constituent of all atoms, but had also been taught by Moseley how to count the electrons in the atom of each element, the situation was altered profoundly. Thus it was at once apparent that potassium with 19 electrons has only to lose a single electron, as J. J. Thomson had supposed, in order to acquire the stable grouping of 18 electrons which is characteristic of argon; and conversely, that chlorine with 17 electrons can acquire this stable configuration by gaining one electron. A motive for the transfer of an electron, and an explanation of the origin of this polar type of chemical affinity, can therefore be found in the exceptional stability of a group of 18 electrons, as contrasted with the relative instability of a grouping of 17 or 19 electrons, around a positively-charged nucleus.[21] Indeed, only one important section of the problem now remains unsolved, namely, that we cannot explain why the properties of an inert gas should appear in successive members of the series

$$2 + 8 + 8 + 18 + 18 + 32 \text{ electrons,}$$

or what feature of the quantum theory dictates the formation of the sub-groups of 2, 3, 4, or 6 electrons, which by their summation give rise to the large groups of Rydberg's series:

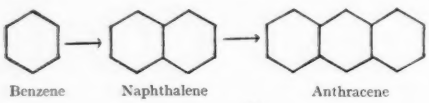
$$2\times1^2 + 2\times2^2 + 2\times2^2 + 2\times3^2 + 2\times3^2 + 2\times4^2 \text{ electrons.}$$

Apart from this, the whole phenomenon of *electro-valence*, as Langmuir calls it, with its attendant theory of the complete and permanent ionisation of mineral salts such as $\overset{+}{\mathrm{Na}}\overset{-}{\mathrm{F}}$ or $\overset{+}{\mathrm{K}}\overset{-}{\mathrm{Cl}}$, seems to be transparently clear.

Nevertheless, just as Berzelius' dualistic theory collapsed when faced with the facts of organic chemistry, so the theory of electron-transfer breaks down in face of the problem of explaining the mutual affinity of *like* elements. This is a serious fault, since the union of like atoms not only dominates the whole of carbon chemistry, but is also responsible for the formation of simple inorganic molecules such as H_2, O_2, N_2, or Cl_2. This second or 'non-polar' type of chemical affinity, however, has also received a clear explanation as a result of the study of atomic numbers. Thus it appears that two atoms, each of which is one electron short of the number required to produce the stable configuration of an inert gas, can acquire this configuration by a simple process of *electron sharing*.[22] In this process a *duplet*, or pair of electrons, is held in common as an integral part of the electronic configurations of the two atoms which it unites, just as the two aromatic rings in naphthalene are united by the two carbon atoms which are common to both rings.

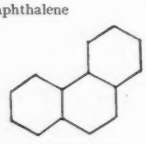
[19] *Phil. Mag.*, 1904, **7**, p. 262.
[20] *J.C.S.*, 1908, **93**, 774.
[21] See especially Kossel, *Ann. d. Phys.*, 1916, **49**, 229.
[22] G. N. Lewis, *J.A.C.S.*, 1916, **38**, 762; "Valence," 1923, p. 74.

In this scheme of electron sharing there does not appear to be any *a priori* reason why two atoms should not be united by sharing *one* electron; and indeed Main-Smith[23] has postulated that this is a normal method of union in co-ordination compounds; but the evidence offered in support of this view is very slender and in general it appears to be a *pair* of electrons that performs this function, just as *pairs* of carbon atoms are shared when one six-atom ring is added to another on passing from benzene, C_6H_6, to naphthalene, $C_{10}H_8$, and then to anthracene or phenanthrene, $C_{14}H_{10}$.



Benzene Naphthalene Anthracene

or



Phenanthrene

Two electrons held in common are therefore the equivalent of a *single bond*, or *covalence* as Langmuir calls it, whilst four or six electrons held in common give rise to a *double bond* and to a *triple bond* respectively.

The groups of eight electrons in the Rydberg series are generally depicted as occupying the eight corners of a cubical octet. A single bond is then represented by a pair of cubes with a common edge, and a double bond by a pair of cubes with a common face; but on this basis the formation of a triple bond would result in a complete superposition of the two cubes, and would thus give rise to a quadruple bond, with four pairs of electrons held in common instead of only three. The new model, therefore, fails to represent the property of forming single, double, *and triple* bonds (and the impossibility of forming a quadruple bond) which are expressed so well by the sharing of a corner, an edge and a face of the tetrahedra of le Bel and Van't Hoff. Indeed, further progress is possible only when we abandon the cubical model in favour of a purely algebraic form of the theory, or else adopt a different geometrical model, *e.g.* by supposing that the octet contains four tetrahedrally arranged duplets instead of eight equally distributed single electrons. This tetrahedral model enables us to see why, in the elements of the first short period, there is no large change of boiling-point on passing from F – F to O = O and N ≡ N; but when we come to carbon, where a quadruple bond between two atoms is impossible, the boiling-point suddenly rises by 3500°. This dramatic rise of boiling-point is obviously due to the fact that the spare bonds, which are left over after uniting the atoms in pairs by single, double, or triple bonds, interlock, until both in diamond and in graphite the molecule extends to the boundary of the crystal, and vaporisation is only possible by disrupting atoms from this enormous molecular complex. If the cubic model were valid, this abrupt change should occur on passing from the double bond of oxygen to a prohibited triple bond in nitrogen, instead of on passing from the triple bond of nitrogen to a prohibited quadruple bond in carbon.

[23] *Chem. and Ind.*, March 28, 1924, **43**, 323.

Origin of Chemical Affinity.

By postulating alternative types of union, the electronic theory of valency enables us to recognise at a glance the existence of two types of chemical affinity, namely, a non-polar affinity between like atoms and a polar affinity between unlike atoms. It has the further advantage of referring both types of affinity to a common cause. This cause, long suspected to be electrical in origin, has at last been disclosed as depending on a mysterious force which compels the electrons, when under the influence of a positively-charged nucleus, to form stable aggregates of 2, 8, 18, or 32 electrons. The origin of these numbers, and of the sub-groups into which they can be further resolved, is, however, a secret which the quantum theory has not yet completely disclosed.[24]

Two Theories of Valency.

During the last fifty years, organic chemists have accepted Van't Hoff's tetrahedron as a correct working model of the carbon atom. This conception of valency was vigorously attacked, however, in 1905, by Werner, who, in his "Neuere Anschauungen" (p. 73 of the English translation), asserted that "Affinity is an attractive force which acts from the centre of the atom and is of equal value at all points on its surface. With such a definition of affinity it naturally follows that separate units of affinity do not exist." In this paragraph, Werner challenges both the limited number and the fixed orientation of the four positions which are available for the attachment of other atoms in Van't Hoff's tetrahedral model. Bearing in mind the distortion of the tetrahedral angles, which is permitted by von Baeyer's 'strain theory,' Van't Hoff's model of the carbon atom can be represented most conveniently by a sphere with four sockets, each socket carrying an elastic rod to represent a bond by which the carbon atom is united to another atom. Werner's alternative conception can be represented most conveniently by Emil Fischer's model, in which the 'atom' takes the form of a sphere covered all over with bristles, a sort of spherical scrubbing-brush, which

[24] An interpretation of the periodic system, based upon the view that each planetary electron in the atom occupies a unique type of orbit characterised by *four* quantum numbers, has recently been described by Landé (*Die Naturwissenschaften*, July 1925, **13**, 604); see also Sommerfeld (*Phys. Zeits.*, Jan. 1, 1925, **26**, 70-74), and Pauli (*Zeits. f. Physik*, 1925, **31**, 765-782).

resembles the involucre of a burdock in that two 'atoms' will stick together at any point of contact, and in any number up to the limits of space available.

Although Werner considered it necessary to denounce Van't Hoff's conception of valency as incompatible with his own more comprehensive views, it is now clear that these two theories are not in fact competing alternatives, since each is correct in its own domain, but incorrect if applied outside it. Thus Werner's theory of valency gives us an ideal representation of the behaviour of the closely packed ions in a crystal of rock-salt, and agrees precisely with the behaviour which we should expect of compounds which are held together only by *electrovalence*, *i.e.* by the mutual attraction of oppositely charged ions. It is, however, incapable of explaining the open lattice structure of the diamond, which can only be arrived at by limiting the number of points of attachment to four, and at the same time fixing their orientation around the atom, precisely as in Van't Hoff's model. This behaviour is characteristic of all compounds in which the atoms are held together by *covalence*, *i.e.* by the real *bonds* of the organic chemist. We therefore have alternative conceptions of valency, namely, Werner's theory, which expresses the type of chemical affinity that is dominant in mineral chemistry, and Van't Hoff's theory, which expresses the phenomena of organic chemistry; and we now find that these two theories correspond precisely with alternative aspects of the electronic theory of valency, which predicts the possibility, and compels us to recognise the real existence, of both types.

The Two Types of Valency.

In general the two types of valency can be distinguished by merely counting the electrons. Thus, since the potassium ion and the chlorine ion have each a complete outer shell of eight *M*-electrons, we cannot replace the electrovalence by a covalence, since this would create a surplus of two electrons over and above those required to complete two stable 'argon' systems. On the other hand, a molecule of chlorine, with a total of only $2 \times 7 = 14$ *M*-electrons, must be held together by a covalence, *i.e.* by sharing two electrons, since if the atoms were torn apart we could only assign a complete octet of *M*-electrons to one atom, leaving the other with a sextet or incomplete group of six electrons. The conversion of the covalence into an electrovalence, as represented by the equation

$$Cl_2 \rightleftharpoons \overset{+}{Cl} + \overset{-}{Cl},$$

may perhaps occur when the bond is broken by the rupture of the molecule when undergoing chemical change; but this ionisation of the bond can only give rise to an unstable condition, which would always tend to revert to a more stable one in which each atom is able to complete its octet.

We can also distinguish the two types of valency by noticing that the 'polar' type of chemical affinity is indefinitely divisible, like Werner's uniform 'spheres of affinity,' but that the real bond of Van't Hoff's model cannot be divided. Thus in rock-salt the chemical affinity of each 'univalent' sodium atom appears to be divided equally amongst six 'univalent' atoms of chlorine and conversely; but in the diamond the four bonds of the 'quadrivalent' carbon atom are used as integers, each bond serving to unite two atoms, and two only. Whenever, therefore, mention is made of residual affinity, or of partial valencies, I at once suspect that these valencies must be *polar* rather than *non-polar* in character. This view was foreshadowed in 1899 by Thiele,[25] when formulating his new theory of *conjugation*, and I do not know of any evidence which would contradict it.

Even more important is the fact that, whilst an electrovalence can act in any direction round the atom, a real bond or covalence is fixed in direction. In the former case there is nothing to prevent the ions from being packed as tightly as their volumes will permit. This condition is realised in the crystal-structure of rock-salt, $\overset{+}{Na}\overset{-}{Cl}$, which is a close-packed aggregate of equal numbers of ions of opposite signs, and of fluorspar, $\overset{-}{F}\,\overset{++}{Ca}\,\overset{-}{F}$, where there are twice as many ions of one sign as of the other. On the other hand, the atoms of carbon in diamond are very far from being close packed, since each atom is surrounded immediately by only *four* other atoms, whereas each of Werner's spheres would be able to make contact with *twelve* other spheres of equal size. Indeed, it can easily be calculated that, if Werner's conception were correct in this particular case, and Van't Hoff's conception were wrong, the close packing of the spheres would increase the density of the crystal in the ratio of 3·5 to 8. Similar open lattices are found in many other crystals, and it is safe to assert that they can always be associated with the presence of valencies which are limited in number and fixed in direction, precisely as postulated by le Bel and Van't Hoff. Thus, if ice and quartz were mere aggregates of oppositely charged ions,

$$\overset{+}{H}\,\overset{--}{O}\,\overset{+}{H} \text{ and } \overset{--}{O}\quad \overset{++++}{Si}\quad \overset{--}{O}$$

we should expect them to crystallise in the same form as fluorspar, where also there are twice as many ions of one sign as of the other. Actually, both ice and quartz crystallise in a totally different manner; and

[25] *Ann.*, 1899, **306**, 87.

the lattice-work of ice is so open that the density of the aggregate is less than 1. We can therefore assert that the atoms of both compounds are united by real bonds and not by the mere electrostatic attraction between oppositely charged ions. A similar argument has already been applied in the case of iron pyrites, FeS_2, where the sulphur atoms are all paired, instead of being distributed uniformly like the atoms of fluorine in fluorspar. The compound is therefore not a sulphide of quadrivalent iron $\overset{--}{S}\ \overset{++++}{Fe}\ \overset{--}{S}$; but a ferrous disulphide, $\overset{++}{Fe}\ \overset{-}{S}$——$\overset{-}{S}$, in which each pair of sulphur atoms is held together by a bond, in addition to carrying a double negative charge. It is, indeed, clear from these examples that the X-ray analysis of crystals provides a very precise experimental method for distinguishing between the two types of valency, and is of fundamental importance for this purpose.

POLAR, SEMI-POLAR, AND NON-POLAR DOUBLE BONDS.

Three years ago I pointed out[26] that since single bonds can be of two types, namely:

(i) Polar, as in $\overset{+}{Na}\overset{-}{Cl}$.

(ii) Non-polar, as in Cl—Cl, H—H or $CH_3.CH_3$;

double bonds should be of three types, namely:

(i) Polar, as in $\overset{++}{Ca}\ \overset{--}{S}$,

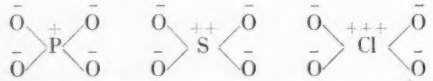
(ii) Non-polar, as in O=O,

(iii) Mixed (or semi-polar), as in $Me_3\overset{+}{N}—\overset{-}{O}$.

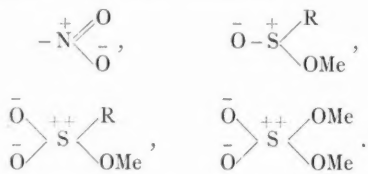
In particular, a mixed or semi-polar double bond was postulated in trimethylamine oxide

$$\overset{+}{N}Me_3-\overset{-}{O}\ (\text{compare } \overset{+}{N}H_4\overset{-}{Cl}),$$

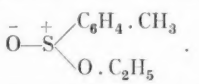
and in the ions of oxy-acids[27]



The existence of this new type of double bond has now been established by two independent experimental methods, depending respectively on the study of molecular volumes and on the detection of molecular dissymmetry. The work on molecular volumes, begun more than half a century ago by Kopp, has culminated in the recent researches of Sugden,[28] who has discovered a function of the molecular volume which is (i) independent of the temperature of observation, (ii) a strictly additive function of the constituent atomic volumes. In these investigations the molecular volumes are reduced to *equal surface tensions*, by making use of a function $\gamma^{\frac{1}{4}}\frac{M}{D-d}$ (where γ = surface tension, M = mol. wt., D = density of liquid, d = density of vapour), which Sugden describes as the *parachor*. The value of this function is increased by 23 units by each *non-polar* double bond, whatever the atoms which it joins, *e.g.* $\rangle C=O$, $\rangle C=C\langle$, $\rangle C=N-$, $-N=O$; but the *semi-polar* double bonds in the systems $\rangle SO$, $\rightarrow NO$ and $\rightarrow PO$ were found to produce a minute *decrement* of molecular volume.[29] In this way the nitro group was shown to contain only one non-polar double bond, whilst the sulphinates, sulphonates, and sulphates do not contain any



More important still is the proof given by Phillips,[30] that the sulphinates (in which the existence of semi-polar double bonds was established by Sugden's measurements of density and surface tension) can be obtained in optically-active forms, as in the case of the ethyl tolylsulphinate of the formula



If the sulphur and oxygen were united by a symmetrical non-polar double bond, the compound would, on the basis of the older space formulæ, be obviously symmetrical. Moreover, since none of the earlier theories of valency was capable of predicting the asymmetry of these compounds, the experimental realisation of this new type of optical activity provides an excellent illustration of the value of the electronic theory of valency, as well as a decisive vindication of the more specialised conception of mixed or semi-polar double bonds. We have here, indeed, a further example of the general rule, already illustrated in the case of Werner's theory of co-ordination, that each new development of the theory of valency has been accompanied by, and has received its final sanction from, the discovery of a new kind of optical activity.

[26] *J.C.S.*, 1923, **123**, 822.
[27] *Trans. Faraday Soc.*, 1923, **18**, 285; *Phil. Mag.*, 1923, **45**, 1105.
[28] *J.C.S.*, 1924, **125**, 1177.
[29] Sugden, *J.C.S.*, 1925, **127**, 1525.
[30] *J.C.S.*, 1925, **127**.

Printed in Great Britain by R. & R. CLARK, LIMITED, *Edinburgh.*

Supplement to NATURE

No. 2954 JUNE 12, 1926

Our Bookshelf.

Studies in Psychology.

Behaviorism. By Prof. John B. Watson. Pp. iv + 248. (London: Kegan Paul and Co., Ltd., 1925.) 12*s.* 6*d.* net.

In his new book Dr. Watson gives a vigorous exposition of his methods and results already familiar to readers of his earlier works, notably "Psychology from the Standpoint of a Behaviorist." It contains, however, some fresh material and foreshadows an ambitious attempt to apply the principles of behaviouristic psychology to all the mental and social sciences. All categories involving reference to consciousness, such as knowing, feeling, striving, are to be eliminated and their place is to be taken by a purely naturalistic study in terms of reflexes and their 'conditioning.' His attitude to the problem of the nature of instinct is more drastic than in his earlier writings. All alleged human instincts are, according to his present view, really habits built up by selection from original responses by processes of conditioning. Emotions, of which there are only three primary ones—namely, fear, rage, and love—are nothing but visceral responses. The 'unconscious' of the psycho-analysts consists, in his view, of bodily and visceral habits that have never been verbalised and cannot be recalled. Modification of behaviour or 'learning' is due to the conditioning of responses and the formation of habits. Thinking is sub-vocal talking, and is made up of laryngeal habits.

The tone of Dr. Watson's exposition is aggressively polemical and confident, but he makes no real effort to deal with the difficulties of his position. This applies particularly to his discussion of 'memory,' 'learning,' and 'thinking,' in each of which recent work has tended to bring out the inadequacy of explanations resting on such factors as recency and frequency of performance, to which alone he appeals. The book contains a number of records of observations, particularly those dealing with the behaviour of infants, which are important and useful, but on the theoretical side it marks no advance, and the claim that the principles embodied in it are destined to revolutionise ethics, religion, sociology, and other social sciences cannot but strike the reader as naïvely extravagant.

M. G.

The Psychology of Handwriting. By Robert Saudek. Pp. xii + 288. (London: George Allen and Unwin, Ltd., 1925.) 12*s.* 6*d.* net.

Graphology, the study of handwriting in popular conception, is placed on something of the same level as palmistry, except that, in the case of the former, experts are sometimes called upon to give evidence as to matters of fact in the law courts. It will therefore, perhaps, come as a surprise to some to find a volume of no small dimensions devoted to the study of the subject on scientific lines, and further, to find that it contains a chapter on the history of the subject. Attempts at 'characterological' interpretation of handwriting begin with a book by Camille Boldo, published at Capri in 1622. In 1830 there was a school of interpretation to which Bondinel, Bishop of Amiens, Cardinal Régnier, and Abbé Flandrin belonged; but the history of graphology really begins with Abbé Hipolite Michon, a pupil of the last named, who was followed by Crépieux Jamin, the most eminent of the French graphologists. It was, however, in Germany that an attempt was made by Georg Meyer and Ludwig Klages, at the end of the last and the beginning of the present century, to place the study on a truly scientific inductive basis.

The author of the present work, in addition to an exhaustive study of the methods of both French and German schools, has had twenty-five years' experience in the study of handwriting, and here puts before his readers the results of his adaptation of these methods to English and American styles and methods in handwriting. So far as they go, his methods, taking into account mechanical and material conditions and the physiology of writing, must be accepted as sound in principle and method. It is when he comes to the psychology of writing that he is on less certain ground. It must be admitted, however, that his reasoned analyses of specimens of handwriting of well-known individuals do indeed appear to tally with the facts so far as generally known.

Animal Life.

Our England: Twelve Open-Air Lessons. By Patricia Johnson. Pp. viii + 104. (London: Methuen and Co., Ltd., 1925.) 2*s.*

This little text-book, which is neither purely geographical nor historical, but contains a little about everything, deserves more than passing mention. In the first place, it represents in substance some of the first broadcast lessons ever given by radio: they were broadcast from the London station in the spring of 1925; and secondly, because they are excellent of their kind. Few books of this size contain so much excellent matter packed within so small a space. The weather, domestic animals, the farmer's year, wild animals, archæology, history, geography, folklore, economics, and the history of traditional civic institutions in England, all find a place, treated in such a way as to stimulate rather than to satisfy inquiry.

The Aquarium Book. By E. G. Boulenger. Pp. 208 + 16 plates. (London: Gerald Duckworth and Co., Ltd., 1925.) 10*s.* 6*d.* net.

The greater part of this book is devoted to popular accounts of a large number of species of aquatic animals. The value and history of aquarium-keeping

are also briefly surveyed and hints given on the management of aquaria.

The book is very attractively written and should have a wide appeal. Its perusal will greatly enhance the interest of visits to the Zoological Society's aquarium and stimulate the enthusiasm of amateur aquarists. It is a great pity, therefore, that care has not been taken to avoid the far too numerous errors, exaggerations, and loose statements in the information provided. Examples of such are a statement on p. 34 that all protozoa have a flagellum, and one on p. 107 that steam-trawling destroys the eggs of the plaice. Misprints and mistakes in punctuation are numerous. On p. 166 the author confers knighthood on Isaak Walton. The few photographs are excellent: the drawings, in some cases good, in others leave much to be desired. On p. 50 the cotton-spinner, *Holothuria nigra*, is misrepresented by a drawing of quite a different species. It is hoped a second edition will appear, carefully edited to remove such blemishes from an otherwise attractive and useful book.

Reproduction in the Rabbit. By John Hammond. With Foreword and Chapter on the Formation of the Corpus Luteum by F. H. A. Marshall. (Biological Monographs and Manuals, No. 4.) Pp. xxv+210+20 plates. (Edinburgh and London: Oliver and Boyd, 1925.) 15*s.* net.

This is an admirable book, containing not only an excellent and up-to-date account of the reproductive phenomena of the rabbits, but also a mass of original results derived from the personal investigations of the author. The book is prefaced by an excellent short outline of the processes involved in the sexual cycle, by Dr. F. H. A. Marshall, who also appropriately contributes the chapter upon the formation of the corpus luteum.

Mr. Hammond's work is clearly written and is well illustrated by charts and half-tone blocks. It will be found indispensable by all specialist students of mammalian reproduction, but will also prove most useful and most interesting to the ordinary biologist interested in a more general way in the phenomena of reproduction.

The Breeding of Foxhounds. By Earl Bathurst. Pp. xiii+132+8 plates. (London: Constable and Co., Ltd., 1926.) 21*s.* net.

The scientific principles of animal breeding are still obscure: yet the success of the practical man, from the days of Jacob's matrimonial venture onwards, are for all to see. Probably the modern dog, particularly the sporting dog, provides the best example of man's skill in moulding wild animals to his purposes; for, if Darwin was right, the raw material was the wolf, the dingo, and the like—most unpromising material out of which to build up a being of almost human intelligence. This book, based, as it is, on the accumulated experience of nearly forty years of breeding hounds (the author being the well-known and successful Master of the V.W.H.-Cirencester Hounds), is deserving of the careful study of all—and they are many—who are interested in the practical problems of hound-breeding. Earl Bathurst is clearly a master of his subject, and does not object to disclosing, as so many practical breeders of animals do, the secrets of his methods. It is open to doubt, however, whether science, Mendelian or other, can do much to aid. The author devotes, it is true, a chapter to Mendelism, but the methods he applies owe their main justification to the practical success which has followed them. The qualities of the perfect hound, we are told, are "voice, nose, drive, stoutness, and looks." The geneticist would scarcely venture to describe these as Mendelian 'unit characters,' or even assert their dependence on 'genes.'

It is interesting to observe how the dread of inbreeding dominates the practical breeder. "Study the pedigrees," says the author, "so as to avoid breeding too closely." Yet we know that, as a matter of practice, close inbreeding was applied by all the great 'improvers' of cattle and sheep, and modern science asserts that inbreeding, in itself, is not harmful. Certain it is that fixity of type can be obtained by this practice and no other. The 'line' breeding which the author practises is, after all, simply a diluted system of this nature. The book is handsomely produced. The photograph of the author's Trouncer, 1923, will excite the envy of every hound lover.

Hygiene and Health.

(1) *The House of Health: What the Modern Dwelling Needs to Be.* By Sir John Robertson. Pp. 192. 2*s.* 6*d.* net.

(2) *Nursing in the Home: including First Aid in Common Emergencies.* By Stella Churchill. Pp. 197. 2*s.* 6*d.* net.

(3) *The Fight against Infection.* By Lieut.-Col. G. E. F. Stammers. Pp. 214. 2*s.* 6*d.* net.

The Modern Health Books. (London: Faber and Gwyer, Ltd., 1925.)

These three examples of the series of "Modern Health Books" which are being issued serve to illustrate the scope and method of treatment of the subjects adopted. The matter is limited to essentials and is dealt with in simple non-technical language, the type and 'get up' are pleasing, and the volumes are light and handy.

(1) Sir John Robertson gives all the essential details which are required to make a healthy dwelling, and in addition to the actual construction of the house itself, discusses the environment, drainage, water supply, and smoke abatement. As regards construction, pisé de terre and steel houses are alluded to, and timber houses are recommended as both comfortable and hygienic. The old-fashioned sash window is recommended as being the best for cottage lighting and ventilation, with which we agree. Tongued and grooved floor boards are advocated, but certainly add to cost. Many small but important practical details are referred to; *e.g.* the size of bath for artisan dwellings, the slipperiness of some baths, enamelled taps to save labour. We are glad to note that the author has a good word to say for the carth-closet in rural districts, and we would emphasise its value in these circumstances as providing a source of manure for the garden now that stable manure is becoming scarce and costly.

(2) A good survey of the art of home nursing is here presented. Practical nursing details are included, and directions are given for the nursing of children, of infectious and some other diseases, and of surgical

cases. Directions are given for the treatment of emergencies (such as fits, drowning, and poisoning), and of some common minor ailments. No caution is given of the irritant effect of formalin in connexion with disinfection, and we have failed to find a mention of that common and alarming ailment of children—spasmodic croup.

(3) Col. Stammers has been able briefly to describe the causation and means of prevention of many of the ills to which flesh is heir. Two brief chapters serve to introduce to the reader the nature of parasites, vegetable and animal, and to give an account of some of the means by which the body resists infection. A fascinating narrative then follows of several important diseases, including plague, cholera, typhoid fever and sleeping sickness, and guinea-worm and tapeworm infections. A short chapter on scientific research is included, which should impart to the non-scientific reader some idea of what research work is.

The text is illustrated with figures of parasites and their intermediate hosts and charts of geographical distribution. We notice a slip in the legend of Fig. 13, where the diagram of the female guinea-worm is stated to be "highly magnified," though in the text the worm is rightly described as being about a yard in length. It would be better also, we think, not to refer to *Tænia solium* and *T. mediocanellata* as the "pig" and "beef" tape-worms respectively, as in the tapeworm stage they are essentially human.

Indian Forestry and Timbers.

India of To-Day. Vol. VI.: *India's Forest Wealth.* By E. A. Smythies. Second edition. Pp. xv + 137 + 12 plates. (London: Oxford University Press, 1925.) 3*s.* 6*d.* net.

FORESTRY is a subject on which the average politician is profoundly ignorant. A very high proportion of the Indian public have hitherto had very little direct interest in the forests. As a people they are extraordinarily economical both in the use of fuel and timber. Only a comparatively small proportion of the population live in the vicinity of the remaining forests. In spite of the fact that enormous quantities of produce are given away annually to rightholders (estimated very conservatively at 1,000,000*l.* worth), the general attitude of those directly interested in the forests is one of grievance against the restrictions of the Forest Department as to free fuel, timber and grazing. This grievance, coupled with the fact that the present annual surplus from Indian forests after approximately seventy years of conservation and development has only increased from 80,000*l.* to 1,300,000*l.*, is reflected in the attitude of the majority of Indian politicians, who in general are hostile to forest development. The present work, prepared by Mr. Smythies in collaboration with provincial officers, is therefore very timely. It emphasises the enormous indirect benefits derived from India's forest estates and their value to the population as a whole; it describes what the Forest Department has already accomplished; and it explains very clearly the urgent need of further investment of capital in the forests if the exchequer in the course, say, of the next fifty years is really to benefit directly from the investments already made.

An Elementary Manual on Indian Wood Technology. By Dr. H. P. Brown. Pp. xiii + 121 + 16 plates. (Calcutta: Government of India Central Publication Branch, 1925.) 4 rupees; 6*s.* 9*d.*

THERE has been a certain amount of prejudice in the past against the use of the microscope for the identification of timber, the reason generally given being that it is impracticable for use in the field. The number of different timbers, however, which now need to be distinguished has increased so enormously that opinion has veered to the other extreme, and many regard any attempt to identify a timber without the aid of the microscope as so much guess-work. J. S. Gamble's "Manual of Indian Timbers" has for many years been the only important work in this particular field, but unfortunately contains no microscopic data. There has consequently been a growing need of a text-book for the training of Indian forest officers in the anatomy of the timbers of India. As Dr. Brown points out in his preface, to teach students in terms of timbers which they will never handle is neither efficient nor conducive of the maximum possible interest. It is to remedy this defect that this volume has been written, and that it will go a long way towards doing so is not to be doubted. It should also prove of value to those interested in the timbers of tropical countries other than India.

The microscopic features of wood are described more fully than the gross features and physical properties, but the latter are quite clearly and concisely set out. Admirable use has been made of a large number of original photomicrographs and drawings, both of which are excellent, and a key is appended for the identification of sixty of the more important Indian woods.

L. C.

Earth Structure and History.

Geological Maps: the Determination of Structural Detail. By Robert M. Chalmers. Pp. vii + 175. (London: Oxford University Press, 1926.) 12*s.* 6*d.* net.

THE study of geological maps and structures is perhaps one of the most difficult parts of any advanced geological course, and until recent years there has been no guidance in the way of text-books available to students. There are now several books from which a selection may be made, and this, the most recent addition to the growing literature of the subject, seems likely to make the widest appeal. It is intended not only for geologists, but also for students of mining, and many of the examples in the text have been chosen to illustrate problems arising in the working of coal seams. The purely geological student, however, will find such difficult structures as recumbent folds quite adequately treated, and it is noteworthy that examples are taken from the Ballachulish and Appin folds.

The author has a wide knowledge of geological evidence and its interpretation, and besides dealing with the familiar topics, outcrops, thickness and dip of beds, faults, etc., chapters are also devoted to igneous rocks and geosynclines, while an appendix gives a brief account of the theory of isostasy. The book can be warmly recommended to teachers and students as a thoroughly successful text-book, while the publishers are themselves a sufficient guarantee that the book is well and attractively printed.

An Introduction to Earth History. By Prof. H. Shimer. Pp. viii+411. (Boston, New York and London: Ginn and Co., 1925.) 12*s.* 6*d.* net.

Prof. Shimer is to be congratulated on having achieved a very definite success in his attempt to compress into a small book a thoroughly adequate, well-proportioned, and completely up-to-date survey of geology and its border subjects. The treatment is far from following the conventional lines usually adopted. Part 1 deals with the 'evolution' of matter and stars, and so leads up to the birth of the solar system and the origin of the earth. The recent tidal theory of Jeans and Jeffreys is briefly summarised, and radioactivity is discussed with the view of applying it later to the measurement of geological time and the problems associated with the earth's internal sources of energy. Part 2 briefly describes the processes at work on the surface of the earth and within it; and at greater length the sequence of events, due to the interaction of these processes, which constitute geological history. Part 3 is devoted entirely to the history of life, and gives in broad outlines a most useful summary of the evidence for and the results of organic evolution.

From the most modern applications of radioactivity to dinosaurs' eggs the book reaches the newest fringes of a rapidly advancing subject, and presents it everywhere as a science in active growth towards maturity. The book is well written, cultured and philosophical in tone, and will serve alike for the general reader and the non-specialising student to give a general picture, described by an authoritative guide from a modern point of view, of the progress that has so far been made in our interpretation of the earth's history and that of its inhabitants.

A Text-Book of Geology: for use in Universities, Colleges and Engineering Schools. By Prof. James Park. (Griffin's Scientific Text-Books.) Second edition, revised and enlarged. Pp. xix+527+72 plates. (London: Charles Griffin and Co., Ltd., 1925.) 30*s.* net.

This comprehensive elementary text-book has enjoyed a quiet popularity for twelve years, particularly amongst mining men, to whom the author, Prof. James Park, is well known for his works on mining and metallurgy. This, the second edition, has been considerably revised, though not so fully as one would have wished, for in many respects it is not adequately up-to-date, and reference to the bibliography definitely shows that many important works of the last decade have not been utilised. Although the first edition contained 598 pages, the present volume is considerably larger because of the adoption of a bigger page-size. It includes new matter dealing with the history of geology, the origin of coral reefs and atolls, mountain building, and the formation of ore deposits. In the revision of the section discussing the age of the earth, the longer estimates of geological time are wrongly ascribed to Joly. The book begins with physical geology and includes a brief summary of mineralogy and petrology. The second part, dealing with historical geology, is noteworthy for the many excellent plates illustrating fossil forms. Special prominence is given to the comparative stratigraphy of Britain, North America, and Australasia. This section concludes with a useful chapter on the development of surface relief, though more attention might have been given to modern work on isostasy and the structure of the Alps. Part 3 deals in two chapters with economic geology and geological surveying.

For elementary students the book thus presents within one pair of covers a remarkably complete survey of the subject, clearly written, and thoroughly well illustrated. It is, however, conventional, after the manner of older text-books. Had it been brought more authoritatively up-to-date, it could have been warmly recommended to British students. As it is, and taking into consideration the high price, it is not likely to be widely adopted except in Australasia, where it should prove particularly useful as a general text-book.

The World in the Past: a Popular Account of What it was Like and What it Contained. By B. Webster Smith. (The Wayside and Woodland Series.) Pp. xii+355+111 plates. (London and New York: Frederick Warne and Co., Ltd., 1926.) 10*s.* 6*d.* net.

This new volume of the "Wayside and Woodland Series" can scarcely be said to reach the usual standard of that admirable collection. It is extremely difficult to write a satisfactory popular account of geological history. The successful author of such a book must be an artist in prose, and he should wander at ease through his subject, presenting it in an attractive and persuasive form and in a friendly and authoritative way; above all he must not patronise the reader or indulge in 'journalistic bromides.'

Judged by the unwritten ideal, this attempt is not altogether a success. It has an old-fashioned flavour and is sprinkled with sentences that will offend the fastidious. As examples of the author's style which justify this criticism we may quote a sentence on p. 100: "Silurian times, the Age of Lime, were not so extensive, perhaps, as their predecessor, the Age of Mud; nevertheless, a million years' duration is the least that can be assigned to them"; and the description of Stegosaurus on Pl. 66: "The last word in Dinosaurion ugliness." Although betraying superficial knowledge, the book is not faulty in its facts. It contains many vivid descriptions of ancient animals and landscapes and is generally light and interesting in style. Many of the illustrations are excellent, and have not appeared before in geological books. More maps should have been included, and a saving in cost might have been effected by omitting some of the colour printing.

Palæontology: Invertebrate. By Henry Woods. (Cambridge Biological Series.) Sixth edition. Pp. vi+424. (Cambridge: At the University Press, 1926.) 10*s.* 6*d.* net.

It is a compliment to this useful and well-known book to find that after five years still another edition has been called for, despite the fact that during the life of the fifth edition it had to compete with rivals that had not previously entered the field. The book has now been revised, with special attention to the ammonites and corals, in connexion with which groups the author acknowledges assistance from Dr. L. F. Spath and

Dr. Stanley Smith respectively. Some new figures have also been added, and a useful feature is the guide to the literature of the subject. For more than thirty years this little book has been indispensable to the elementary student of invertebrate palæontology, and it remains, as before, clear, concise, and authoritative.

Economic Geology.

Clay and what we Get from it. By Alfred B. Searle. Pp. 178. (London: The Sheldon Press; New York and Toronto: The Macmillan Co., 1925.) 3*s.* 6*d.* net.

Except for a brief introductory account on the nature, mode of occurrence and origin of clays, and a closing chapter of quotations from prophets and poets, this book deals with the industrial applications of clay. It is, indeed, of special interest as showing to what a large extent clay figures as a thing of usefulness in human affairs. The author is full of knowledge of the subject, and in these interesting pages he has succeeded in conveying much of it, as well as some of his enthusiasm, to the reader. The book well deserves a place in the Popular Science series of the Sheldon Press.

Geological Survey, Scotland. The Economic Geology of the Ayrshire Coalfields. Area 1: Kilbirnie, Dalry and Kilmaurs. By J. E. Richey, G. W. Wilson and E. M. Anderson; with Contributions by C. H. Dinham. Pp. vi+91+2 plates. 2*s* 6*d.* net. Area 2: Kilmarnock Basin, including Stevenston, Kilwinning and Irvine. By E. M. Anderson; with Contributions by G. V. Wilson. Pp. vi+107+2 plates. 3*s.* net. Sheet 8: Vertical Sections illustrating the Ayrshire Coalfields, Areas 1 and 2. On the Scale of 40 ft. to 1 in. Arranged by E. M. Anderson and J. E. Richey. 2*s.* 6*d.* net. (Edinburgh and London: H.M. Stationery Office; Southampton: Ordnance Survey Office, 1925.)

These two volumes may be looked upon as the continuation of the series of memoirs on the coalfields of Scotland, a commencement on which was made some time ago with the Central Coalfield. The present volumes cover the greater part of the Ayrshire Coalfield, which for the purpose of description is divided into two areas, Area No. 1 comprising the main portion of the coalfields of central and northern Ayrshire, whilst Area No. 2 covers the southern portion of the coalfield, of which Kilmarnock may be looked upon as the centre.

The arrangement in both volumes is necessarily somewhat similar, commencing with an account of the general geological structure and then describing in detail each formation, beginning by the lowest known in the district. The coal seams are naturally described in much detail, but attention is also paid to the other minerals of economic importance, such as the ironstones, limestones, fireclay and other clays, building stones, sands, refractory materials, stones for road metal and other purposes. In the memoir upon Area No. 1 there is an appendix giving analyses of a number of these minerals of economic importance, and it is rather to be regretted that this excellent example has not been followed in the volume dealing with the second area.

It need scarcely be said that the work is admirably done, and that these two volumes contain a wealth of information which will be of the utmost value to the mines working in this important coalfield.

General Physics.

Marvels of Sound, Light and Electricity: an Introduction to some Physical Phenomena for Young Students. By Percival G. Bull. Pp. vii+221. (London: George Routledge and Sons, Ltd., n.d.) 6*s.* net.

This book, we are told in the preface, is not intended as a text-book, but is expected to fill the rôle of arousing such interest and enthusiasm as will induce the spare-time reader to proceed to a more detailed and systematic study of physics. If the reader is not an absolute beginner in physics, we are of opinion that the author has probably succeeded admirably in his task. But we are afraid that the opening pages of the book make too great a demand upon the absolute beginner. Such a reader must of necessity find the references to radiation, the spectrum, longitudinal waves, and the like (although these are explained in greater detail later), rather too difficult; which would be a great pity in view of the general excellence of the book once these first pages are passed.

The author begins with an explanation of the phenomena of wave motion and their application to sound. He then passes to the study of light and colour, and to the study of the invisible portion of the spectrum. The interpolation of a chapter on optical illusions is interesting and well done, but makes a break in the continuity of the theme. It is followed by a chapter on cathode and X-rays and radioactivity, after which the book is rounded off with a description of experiments with high-frequency electric currents and high-tension discharges. The style and production are both attractive, and we can confidently recommend a place for the book in all school libraries.

Elementary General Physical Science. By W. R. Jamieson. Pp. 63+88+147+x+16 plates. (Melbourne: Brown, Prior and Co. Pty., Ltd., 1926.) 8*s.* 6*d.* net.

We extend an unqualified welcome to this book. Published in Australia, it is the work of the senior chemistry master at the Scotch College, Melbourne. If it is to be taken as typical of the spirit that animates science teaching in the Commonwealth, then Australia has undoubtedly much to offer to British teachers of science in schools by way of example. If, on the other hand, it is not typical, then Mr. Jamieson is a pioneer worthy of every encouragement. He aims in effect at the broadening of the approach to the study of science. This is a plea which has found increasing expression at the various conferences of the Science Masters' Association, and, so far as the physical sciences are concerned, the book under notice shows how well this can be done. Prof. Rivett, of the University of Melbourne, hints in a foreword at the advent of a companion volume on similar lines dealing with biological science, and we cordially hope this will speedily appear.

Want of space makes it impossible for us to go into details. We quote from the preface: "Without sacrificing in any degree the exactness and accuracy which are an essential feature of true science, the author has sought to inculcate ideas and express the spirit of science. . . . Broad treatment rather than minute and detailed study has been aimed at." Observing on the whole a historical sequence, the formal divisions of chemistry, physics, mechanics, and astronomy are all

linked up and blended in the most interesting fashion; and if the shackles of tradition and examination make it difficult for the book to be adopted in many schools at home, we can at least contend that no teacher of science will be the poorer in ideas for the outlay which purchase of the book involves. I. B. H.

Quantum Theory.

Atomicity and Quanta: being the Rouse Ball Lecture delivered on May 11, 1925. By Dr. J. H. Jeans. Pp. 64. (Cambridge: At the University Press, 1926.) 2*s.* 6*d.* net.

THOSE who have at any time listened to Dr. Jeans are well aware of his skill and charm as a lecturer; these qualities were amply sufficient to make a success of a lecture which is on paper a little disappointing. Unfortunately, the necessities of a popular lecture on an abstruse subject inevitably lead to a certain superficiality, especially in dealing with its peculiar difficulties. For example, Dr. Jeans disposes in the usual way of the conflict between the quantum theory of radiation and the undulatory theory, by limiting the application of the two theories to different types of phenomena: the quantum theory applying to those arising from the interchange of energy between matter and radiation, and the undulatory theory to those connected with radiation travelling without interchange of energy with matter. When, however, he tries to bridge the gap, he does not adopt the almost mystical attitude towards this fundamental problem which many physicists have and may still feel obliged to maintain in spite of the advent of the new quantum mechanics, but resorts to arguments which seem unnecessarily crude. He emphasises the difficulty of obtaining reversibility in systems in which spherical waves play an important part, and suggests the introduction of 'advanced' as well as 'retarded' potentials in order to obtain it. The physical conception which this involves is, however, so difficult that it seems questionable whether any theory which requires it can ever be intellectually acceptable.

For those of Dr. Jeans's audience with the awakened mind and some familiarity with the subject, the lecture was excellent, vivid, with sufficient emphasis and balance of structure to make it striking and easily remembered. It must have given such a listener a clear-cut and manageable picture of much modern work that he had found puzzling before, and there will no doubt be many readers of the same type to whom the reprint will be profitable and congenial reading.

The Quantum Theory of the Atom. By George Birtwistle. Pp. xi+236. (Cambridge: At the University Press, 1926.) 15*s.* net.

THE quantum theory in its applications to atomic physics has developed so rapidly, that a textbook, giving a fairly comprehensive and orderly account of the subject, has become an urgent necessity. Mr. Birtwistle has made a valiant, and on the whole a very successful, attempt to supply this need, and students of the subject will have cause to be grateful to him for his very clear exposition of it. The author has succeeded in compressing into his 233 pages of text a surprisingly complete account of the subject from the earliest speculations of Planck and Bohr to the latest work of Sommerfeld, Kramers and Heisenberg.

The treatment is entirely mathematical, and no attempt is made to discuss the physical and experimental basis of the subject. At the same time the author has, we imagine, had in mind the necessities of the student of pure physics, and very kindly and wisely has included chapters on those developments of classical mechanics—the Hamiltonian equations, the Hamilton-Jacobi equation, and Lagrangian methods—which, while they form the basis of much of the quantum mechanics, are unfortunately not part of the equipment of the average student of physics. These chapters add very considerably to the value of the book.

The writer of a textbook must adopt some kind of "Principle of Selection," and naturally some things are omitted which a reviewer might wish to have seen included. In particular Mr. Birtwistle passes over in, possibly discreet, silence the views of the ultra-modern school in which the quantum is handled as if it were a material particle; and, perhaps more seriously, the chapters on X-rays and γ-rays are somewhat inadequately treated. The author has, however, given us so much that is excellent that it would be unjust to complain because he has not included still more. We hope that the rapid exhaustion of this first edition will enable the author to keep the book as thoroughly abreast of the subject as it is at present.

Radio Communication.

Broadcast Reception in Theory and Practice. By J. Laurence Pritchard. Pp. xi+259. (London: Chapman and Hall, Ltd., 1926.) 8*s.* 6*d.* net.

DURING the last two or three years amateurs who are enthusiastic about radio communication have attempted, in some cases successfully, to increase their knowledge by reading standard books on the subject. Probably they began by constructing a radio set from given instructions. Wanting to learn the theory, many found that the ordinary books made too great a demand on their knowledge of the principles of electricity. This book has been written for their use. Formulæ are given but not proved. Confidence in them, however, is obtained by following out the working of numerical examples. The experimenter is then told how to construct his own coils, condensers and resistances, emphasis being laid on important practical details.

A useful chapter is given on how to detect and remedy faults in a receiving set. It is pointed out that the most probable seat of the trouble is the high-tension battery. This is indicated when the signal strength becomes weak, accompanied by crackling noises similar to atmospherics but more persistent. This is generally due to the H.T. battery becoming exhausted and internal disintegration being set up. The zinc containers of the cells get eaten through, soldered intercell connexions become affected, and gas is evolved which makes its way through the pitch or other filling used. The cells quickly polarise and the voltage falls. If a high-resistance voltmeter be available this fault is readily discovered. But if not, it is necessary to substitute a new battery for the suspected

battery to find out if it is at fault. External connecting wires are sometimes broken inside their insulated coverings. Search should be made for this fault. Telephones occasionally give trouble. Every pair of telephones should give a healthy click on being connected to a battery composed of a penny and a shilling separated by a piece of wet tissue-paper. If they are defective they should be sent to the makers for repair. Trouble is sometimes experienced by valve legs of the split type failing to make good contact. The remedy is simply to open the slits slightly by the aid of a knife.

Loud Speakers, their Construction, Performance and Maintenance: a Practical Handbook for Wireless Manufacturers and Traders and for all Wireless Amateurs; containing Notes on the Selection of a Loud Speaker and on the Detection and Remedying of Faults. By C. M. R. Balbi. Pp. xv + 96. (London: Sir Isaac Pitman and Sons, Ltd., 1926.) 3*s.* 6*d.* net.

THE science of sound reproduction by means of a loud speaker is one of ever-growing interest and importance. This little book gives a brief but fairly complete résumé of the subject. The various forms of loud speaker can be classified under three main heads. The first class may be called electro-magnetic. In this class are the well-known Amplion, Brown, Western Electric and Lumière loud speakers. In the second class are those which utilise the phenomena of friction or of the electrostatic attractions produced at the face of semi-conductors. The Frenophone is an example of the former and the Johnsen Rabbek of the latter. In the third class are included many which depend on curious physical phenomena. In this class are the arc loud speaker invented by Duddell, the air-blast, the jet of water, the piezo electric, the crystal, the hot wire, the thermophone and the condenser loud speakers. The mere enumeration shows the variety of physical principles employed all leading when applied to very similar results.

A good description is given of the Western Electric public address system. It is now possible for a public speaker to address a million people at once, and the speaker's voice can be plainly heard at a distance of 1000 feet. The electric power required for these installations is about two kilowatts. With very large assemblies it has been found necessary to provide observing stations at various points in the audience. The observers stationed at these points communicate with the operator by portable telephone sets. A chapter of advice to those intending to purchase loud speakers concludes the volume. So many variables, such as the power and distance of the broadcasting station, have to be taken into consideration that it is only possible to give vague advice. Notes on various types of commercial loud speakers are given, but they would have been more useful if less praise and more criticism had been given.

The Radio Press Year Book 1926: the Wireless Book of Reference. Edited by John Scott-Taggart and Percy W. Harris. Pp. 169. (London: Radio Press, Ltd., 1926.) 1*s.* 6*d.*

MUCH interesting information is given in this little book which will be of value to those desirous of improving their radio-receiving sets. Short sections are contributed by well-known radio engineers. P. W. Harris, for example, compares American and English radio conditions.

As a matter of history, the first daily broadcasting of a programme was made from the well-known K D K A station at East Pittsburgh. In Great Britain Mr. Godfrey Isaacs and the Marconi Company broadcast concerts from Marconi House before the B.B.C. was formed.

In the early days, the Americans were greatly troubled by what they called 'squealing' receivers. To-day, thanks mainly to neutralised high-frequency couplings, the receivers sold in the United States are strictly non-radiating, and it is possible to listen to distant stations, even from the most crowded districts in New York and Chicago, without hearing the faintest trace of an oscillation. The U.S. Government allots definite wave-lengths to the broadcasters and makes them adhere to them very closely. One regulation which sounds curious to British readers is the prohibition of what is called 'canned music,' that is, the music made by gramophone records and player pianos. A useful regulation by the U.S. Government which might be copied with advantage in Europe is that a certified operator is on watch during broadcasting hours, so that in the event of an S.O.S. signal being heard, the broadcasting transmission may be stopped. The section on how to select a valve is a useful one. Although many purchase dull-emitter and bright-emitter valves and talk glibly about them, yet few have any accurate knowledge of their main characteristics. Lists are given of practically all the valves on the market, and the values of their filament ratings, voltages, internal impedances, and amplification ratios are all given.

Many characteristic diagrams are given to illustrate their working. The list of amateur call signs now occupies 30 pages, and there is a long list of radio societies.

The Motor Car and its Engine.

The Book of the Light Car. By E. T. Brown. Pp. vii + 155 + 12 plates. (London: Chapman and Hall, Ltd., 1926.) 7*s.* 6*d.* net.

THE modern light car has been so far perfected and the motor industry so well organised that it is possible and common for persons completely innocent of mechanical knowledge to motor with satisfaction and safety. Many readers of NATURE even may fall within this class and will, nevertheless, feel curious about the construction and working of what is so easily controlled from the driving-seat. For such, Mr. Brown has written clearly in a book well paragraphed and indexed, so that answers to most of the inevitable questions can be turned up in a moment. Here and there the fastidious may be tempted to query the scientific precision of statement or the literary elegance of motoring jargon, but such will probably be in the minority. Again, in places mention is made of certain important parts such as the 'accelerator' and 'throttle,' without any explanation of their construction and mode of operation, but such omissions do not seem numerous, and the book may be commended to those for whom it is intended. H. J. H.

The Economics of Carburetting and Manifolding: Vaporising and Distributing Liquid Fuel in a Motor Car Engine. By Robert W. A. Brewer. Pp. vii+176. (London: Crosby Lockwood and Son, 1926.) 12*s.* 6*d.* net.

THIS book deals with a problem which is of interest to both motor spirit producers and motor engineers. The great increase in the requirements of fuel for internal combustion engines during the past decade has necessitated the production of the maximum quantity of motor spirit from a given quantity of crude material. One method by which this is being effected is by raising the upper limit of the distillation range of the motor spirit fraction. The high boiling constituents, which are thereby included, have rendered it more difficult to vaporise the fuel completely. The author professes to deal with the problem of using such fuels in motor car engines satisfactorily and economically under all conditions of operation, and the book supplements the author's book on "Carburation," where fuels, principally of the more volatile nature, are examined.

The problem is attacked chiefly from the point of view of the design of the induction system (inlet manifold), and various interesting reports and papers which have been issued by the Bureau of Mines in the United States, Society of Automotive Engineers, and others are summarised. A brief account of the author's work on the design of inlet manifolds and descriptions of other systems are also given, and a chapter is devoted to the problem of the dilution of the crank case oil.

The book would appear to be primarily intended for motor engineers. In attempting to make clear to the technical reader the scientific principles involved in vaporising and distributing liquid fuels in motor car engines, the author has been led to use terms which are vague and undefined. The various units used are also somewhat confusing. The book, however, is useful in bringing to the notice of motor users and designers the problem of the efficient utilisation of the high boiling motor spirits which are now on the market.

Miscellaneous.

Recent Advances in Physical and Inorganic Chemistry. By Prof. Alfred W. Stewart. Fifth edition. Pp. xi+312+6 plates. (London: Longmans, Green and Co., Ltd., 1926.) 18*s.* net.

PROF. STEWART'S excellent and useful book is too well known to make any lengthy notice of it necessary. The present edition has all the good qualities of its predecessors, and keeps the student always stationed at the growing point of physical chemical knowledge. Only five chapters have survived from the 1920 edition, and a dozen new chapters have been written for this edition, dealing with hafnium, the isobares, the results of mass-spectrography, the segregation of isotopes, atomic structure, active hydrogen, new hydrides, intensive drying, and Tesla-luminescence spectra. On the whole, the discussion of these various topics has been very well done, and the general student of chemistry is fortunate in having within comparatively small compass all that he requires in order to understand the present position of knowledge in the respective fields.

Palgrave's Dictionary of Political Economy. Edited by Henry Higgs. Vol. 3: N-Z. Pp. xxiii+849. (London: Macmillan and Co., Ltd., 1926.) 36*s.* net.

THE editor and the publishers are to be congratulated on the completion, by the appearance of the third and last volume, of the new edition of Palgrave's standard work. Sixteen years have elapsed since the publication of the first edition; the present edition may be expected to serve the needs of students of economics for as long a period.

The third volume reaches the high standard of excellence to which the first two attained; like those, it reprints the articles as they stood in the original edition and supplements them by others either entirely new or in continuation of old themes. Thus the account of the National Debt is brought down to the year 1923; and problems of recent growth and importance are given ample and authoritative consideration. Social legislation in all its branches is brought up-to-date; there is a very useful statement on the Tariff Reform movement; the article on Socialism is full and instructive; and it is a sign of the times that the appendix contains an article on "The Need of Trained Inquirers into Social Conditions."

An outstanding feature of the volume is its provision of adequate biographies of both British and foreign economists, and not the least useful portion of these is the bibliography attached to each. Indeed, the book-lists throughout the work, like the detailed index at the end, will be found of exceeding great value.

Tin and the Tin Industry: the Metal History, Character and Application. By A. H. Mundey. (Pitman's Common Commodities and Industries Series.) Pp. xiii+130. (London: Sir Isaac Pitman and Sons, Ltd.; n.d.) 3*s.* net.

THE author of this book has succeeded in setting out, in inexpensive and handy form, a concise account of the numerous industrial applications of tin and its alloys. Very little is said about the mineralogy, geology and mining of tin ores, and smelting is referred to very briefly. The book is well illustrated, and should prove helpful to those interested in the commercial aspects of this very useful metal.

The States of Aggregation: the Changes in the State of Matter in their Dependence upon Pressure and Temperature. By Gustav Tammann. Authorised Translation from the second German edition by Dr. Robert Franklin Mehl. Pp. xi+297. (London, Bombay and Sydney: Constable and Co., Ltd., 1926.) 24*s.* net.

STUDENTS and others interested in the heterogeneous equilibria of one-component systems will welcome this translation of Tammann's excellent work "Aggregatzustände," a notice of which appeared in these columns. It suffices to say that Dr. Mehl has produced an accurate and smoothly reading translation, and has thereby made the work available to an extended circle of readers.

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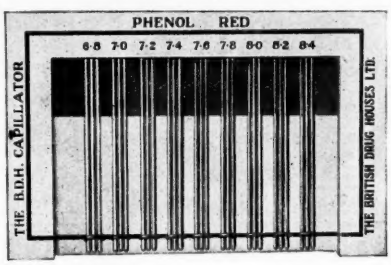

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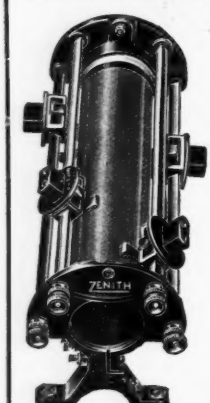

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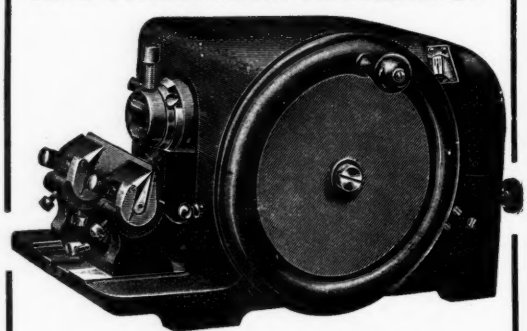

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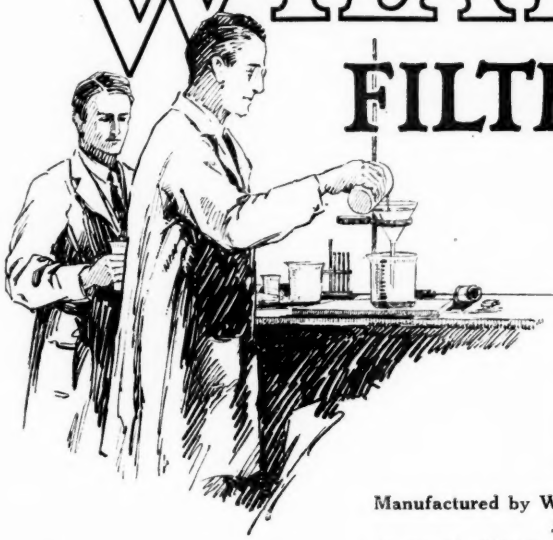

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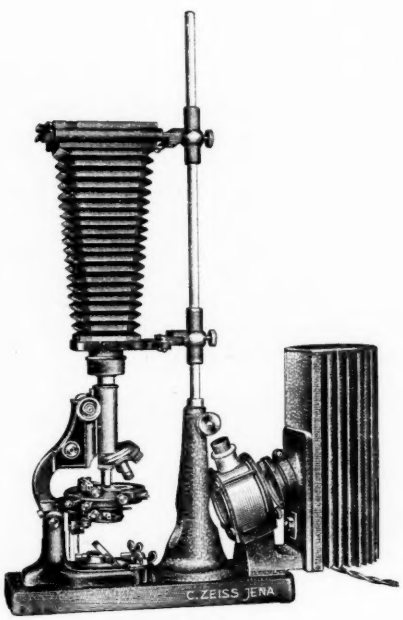

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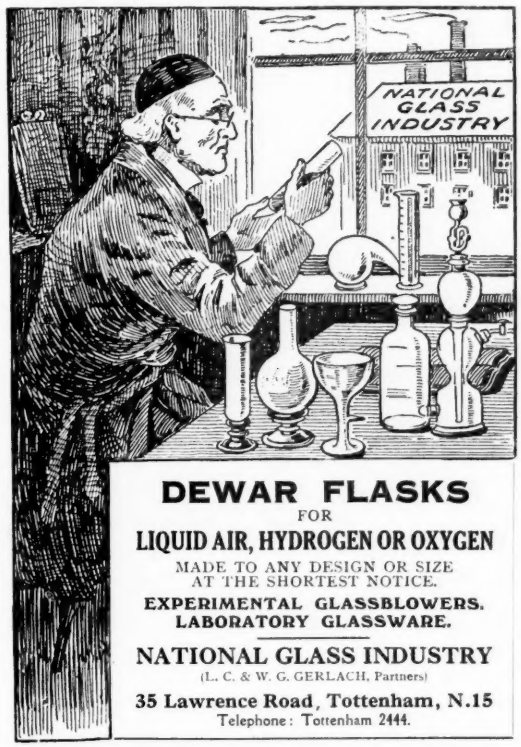

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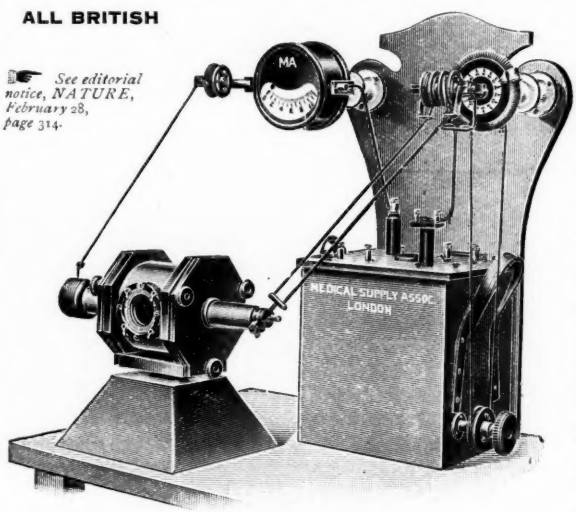

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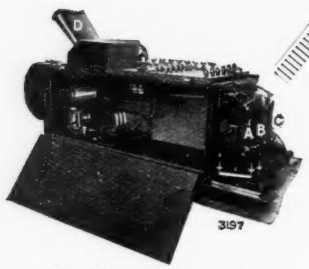

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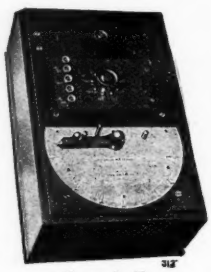

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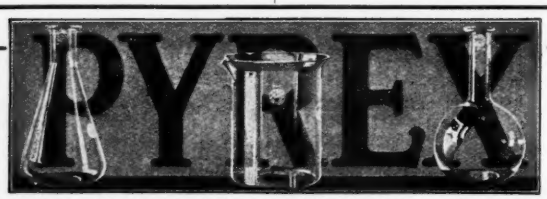

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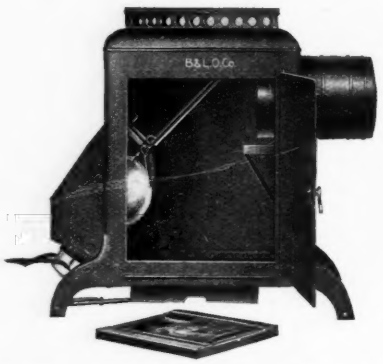

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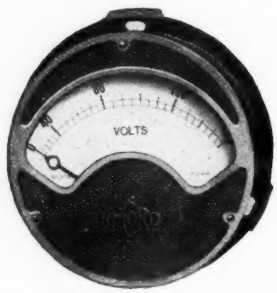

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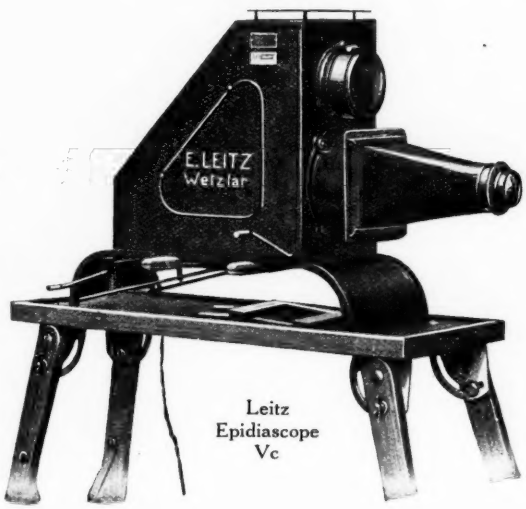

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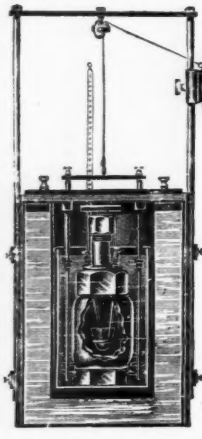

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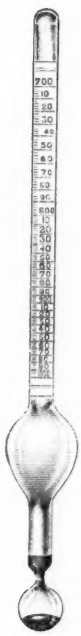

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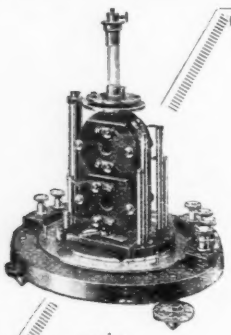

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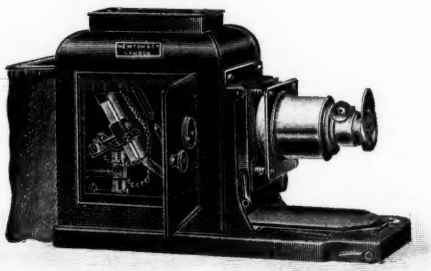

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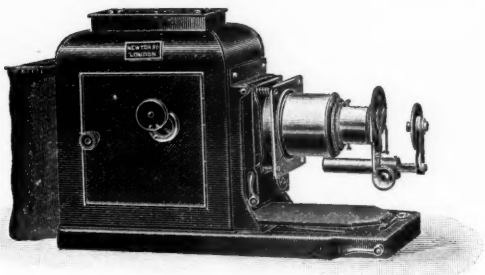

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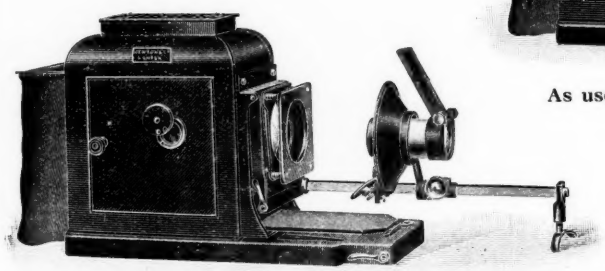

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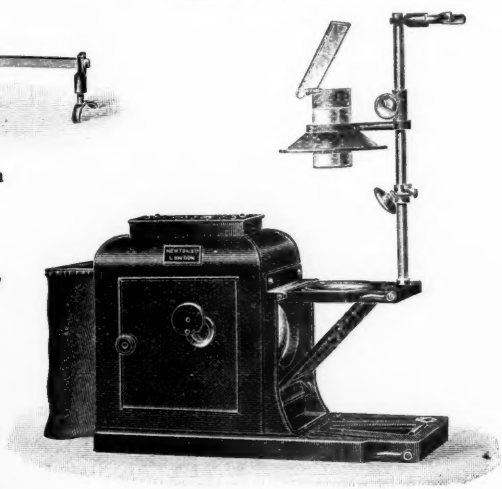

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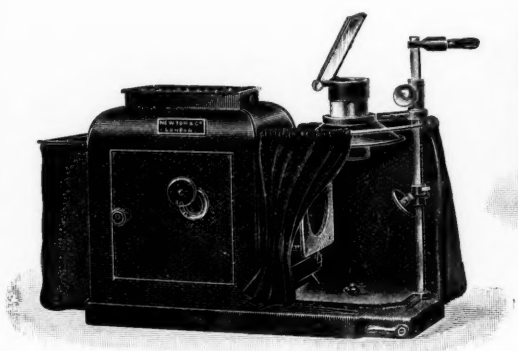

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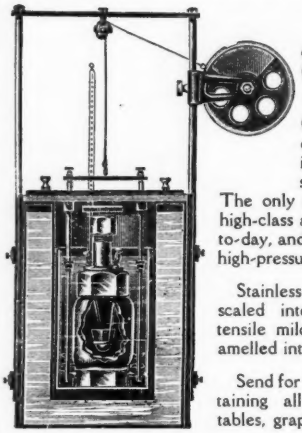

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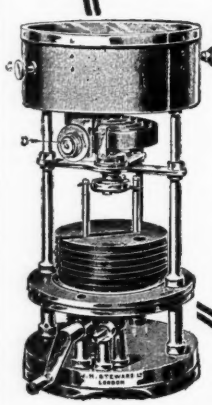

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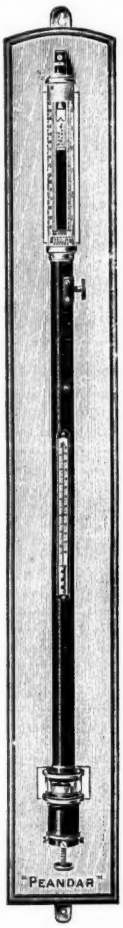

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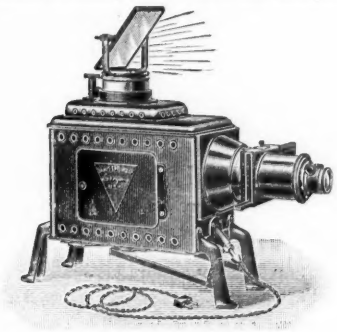

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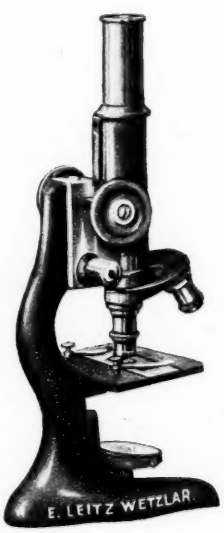

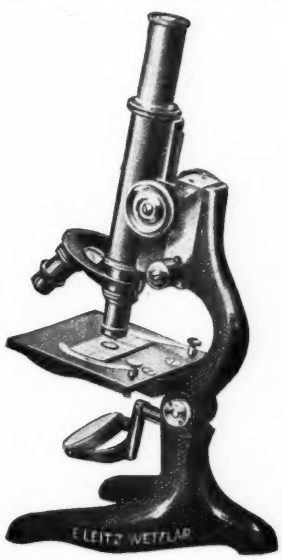

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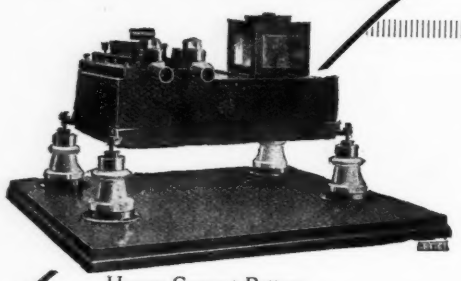

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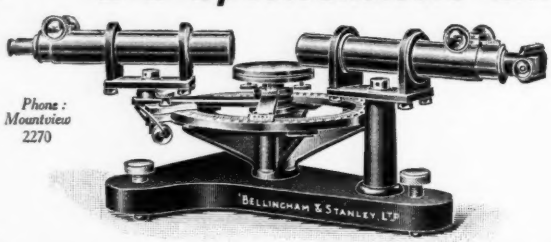

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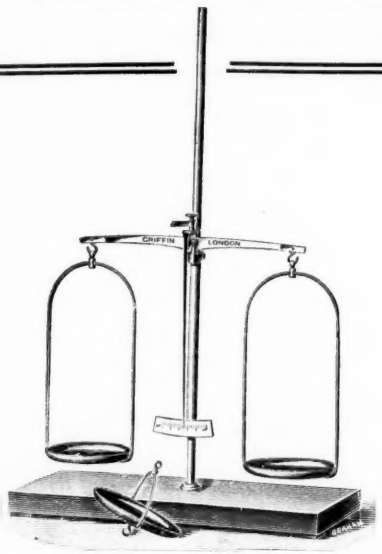

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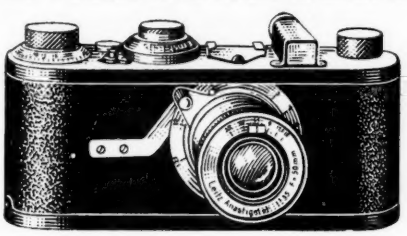

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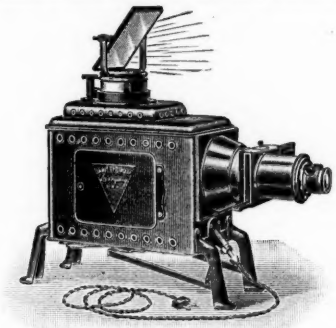

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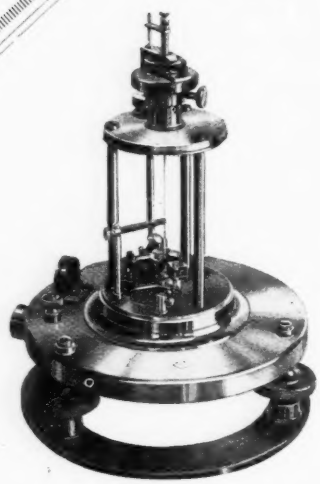

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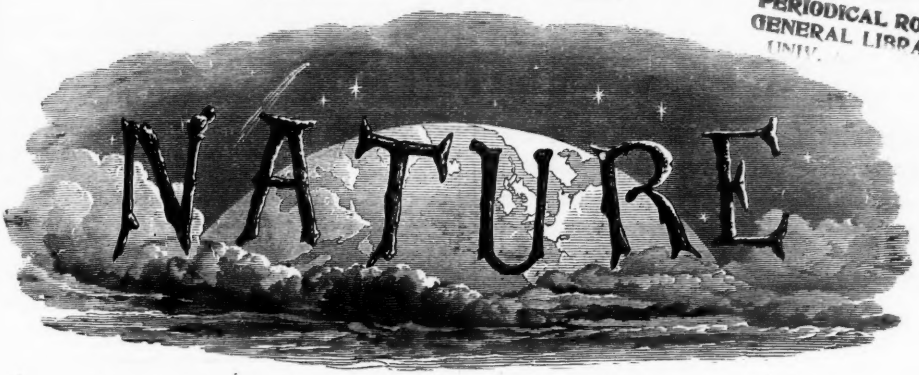

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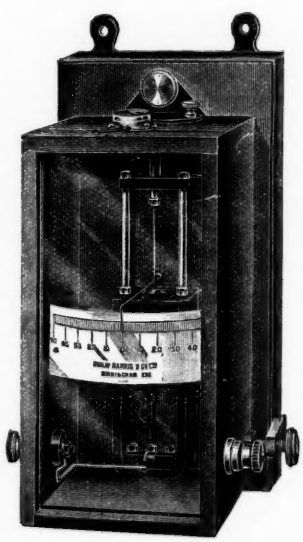

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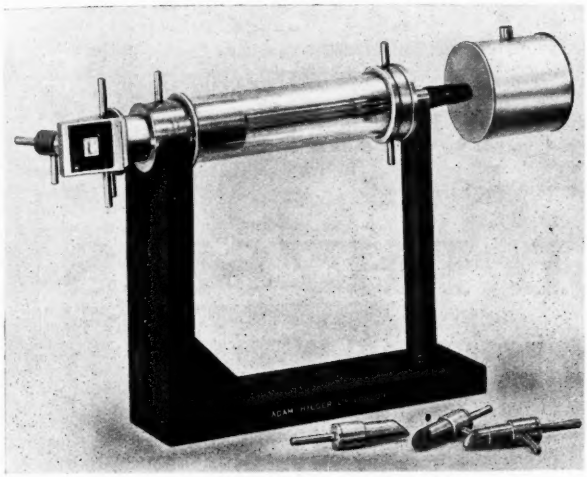

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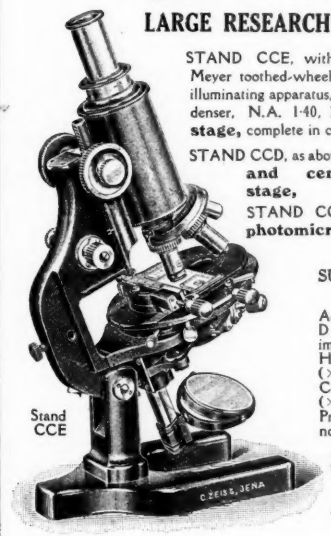

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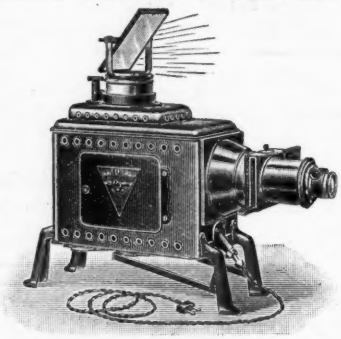

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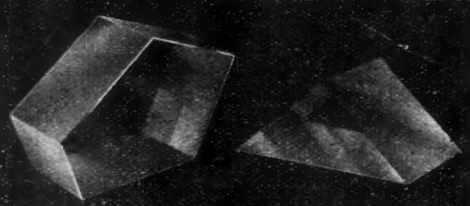

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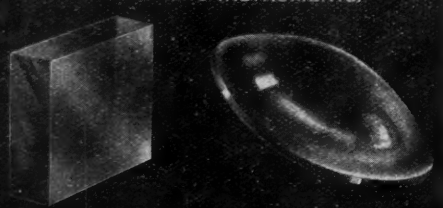

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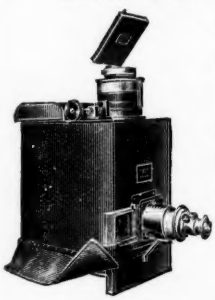

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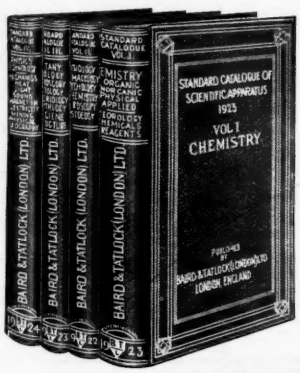

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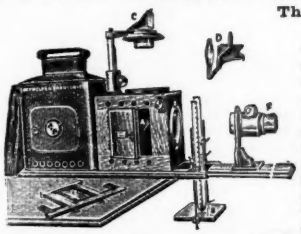

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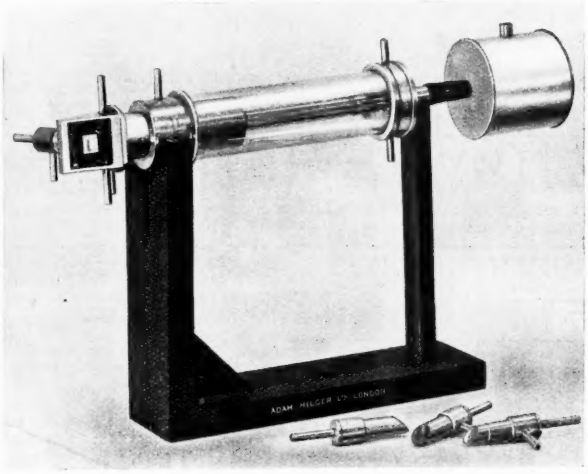

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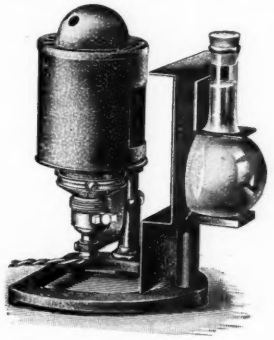

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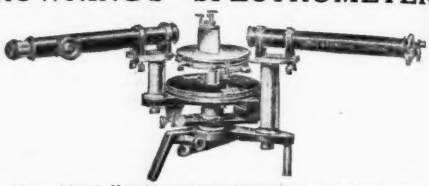

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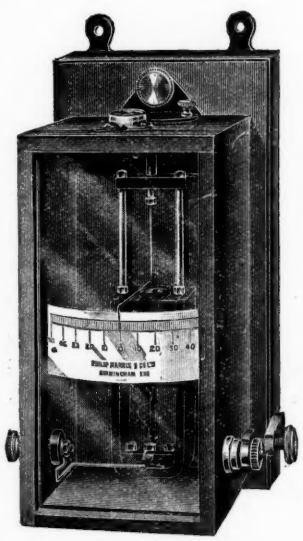

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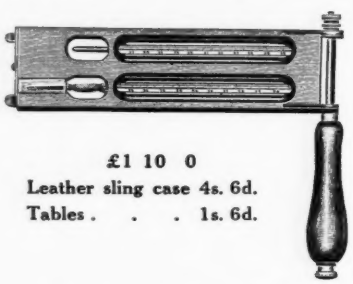

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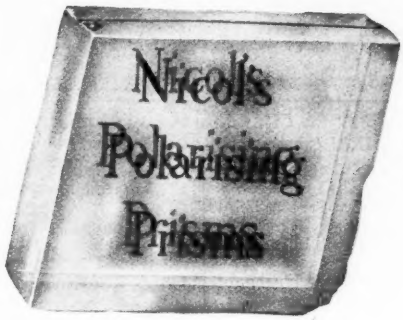

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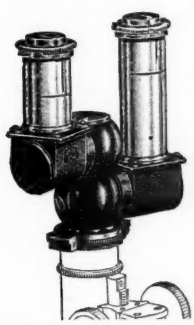

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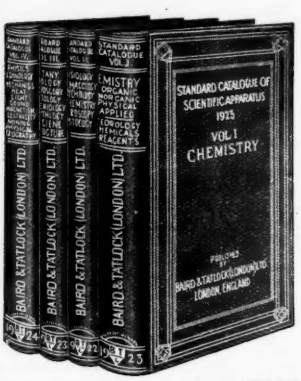

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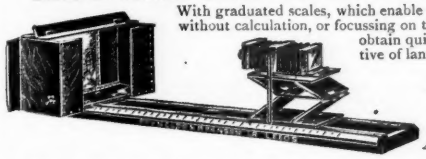

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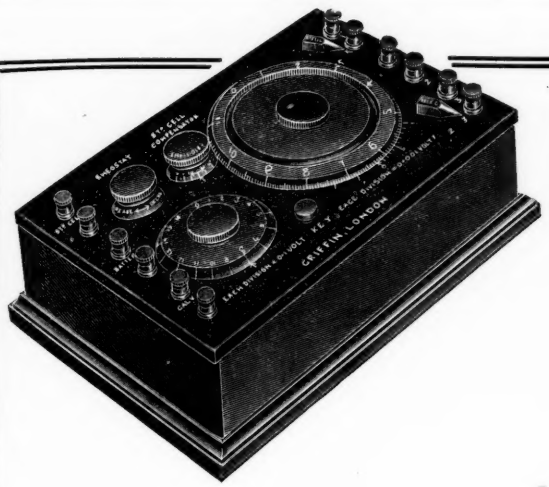

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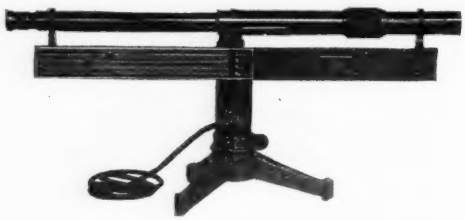

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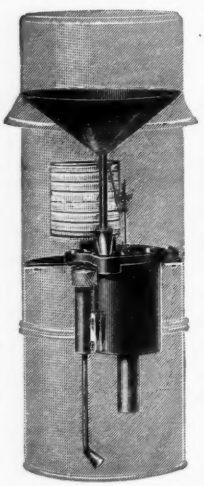

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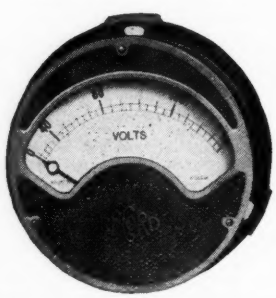

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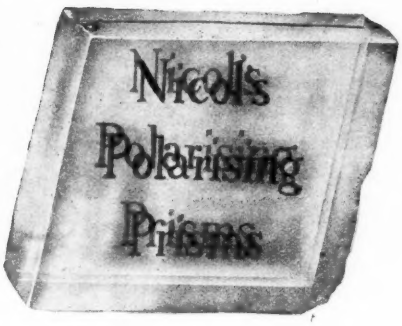

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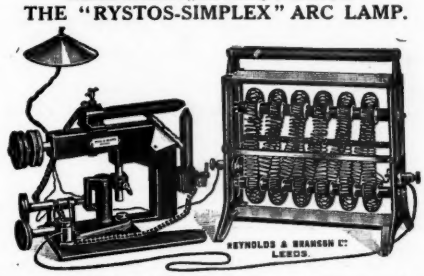

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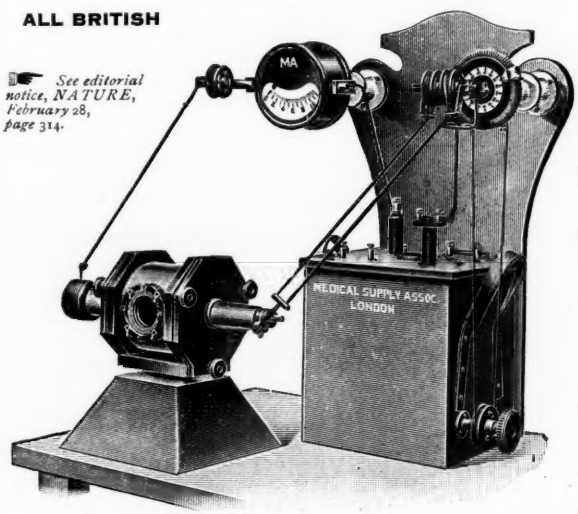

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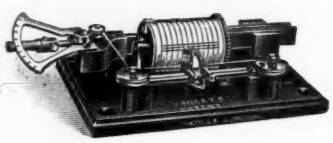

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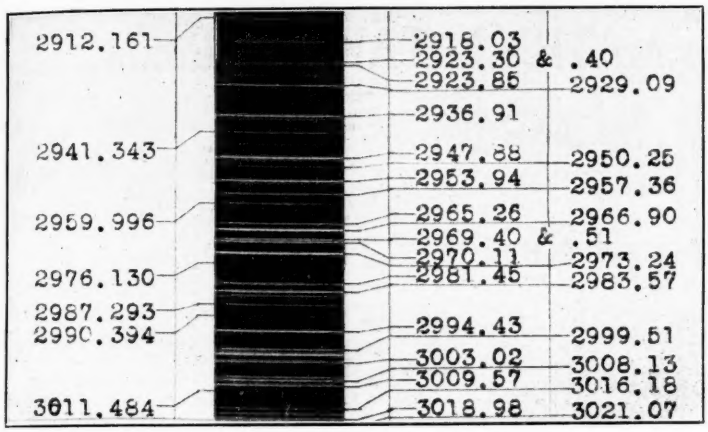

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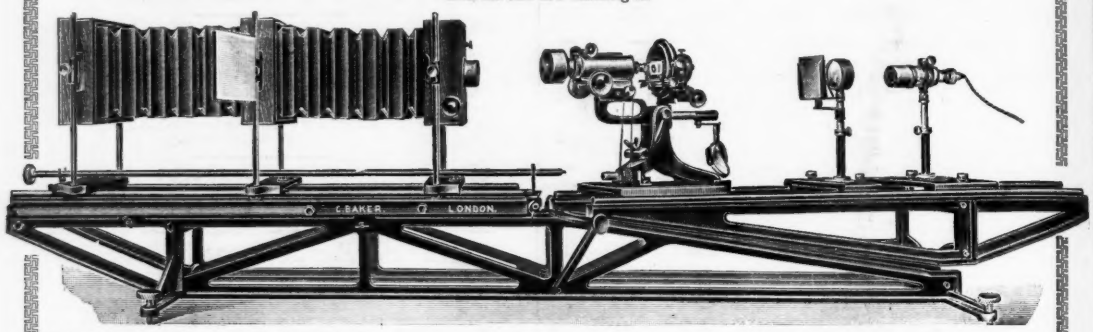

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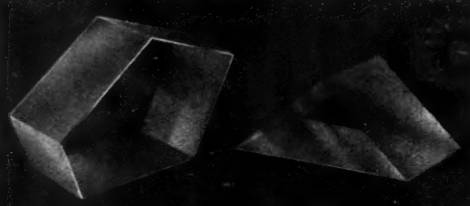

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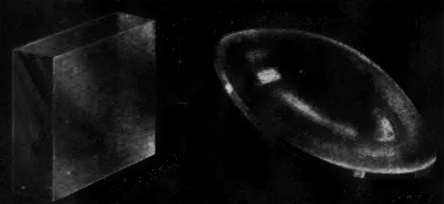

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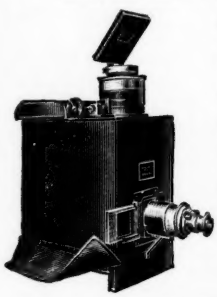

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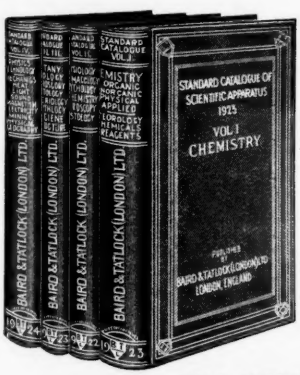

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Candidates must send in their names to the External Registrar, GEORGE F. GOODCHILD, M.A., B.Sc., with any attestation of their qualifications they may wish to submit, by Monday, February 22, 1926. (Envelope should be marked "Examinership.")

It is particularly desired by the Senate that no application of any kind be made to its individual members.

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E. C. PERRY,
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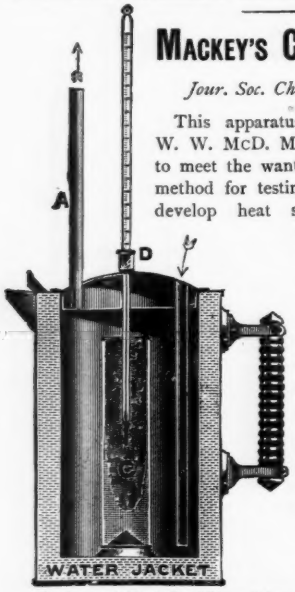

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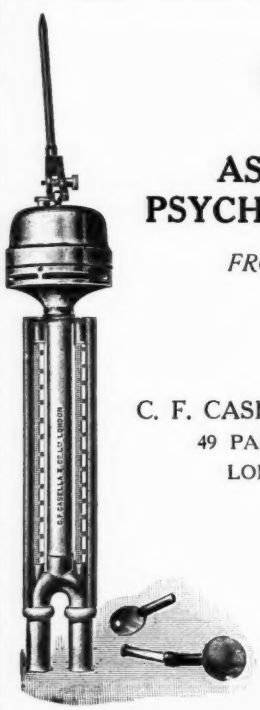

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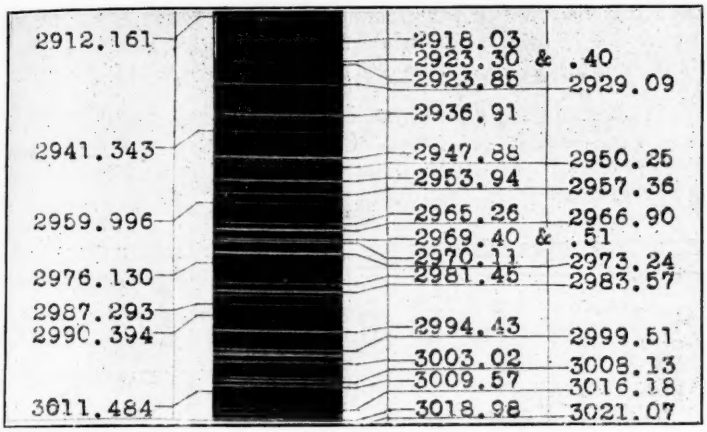

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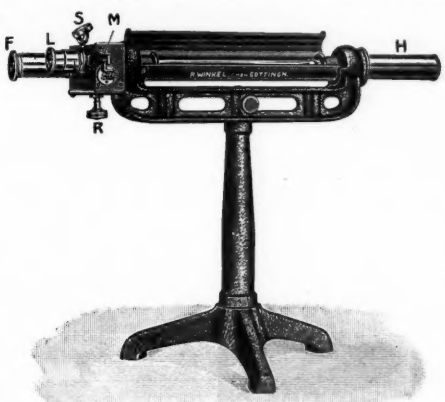

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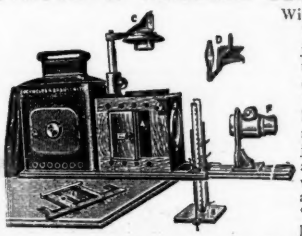

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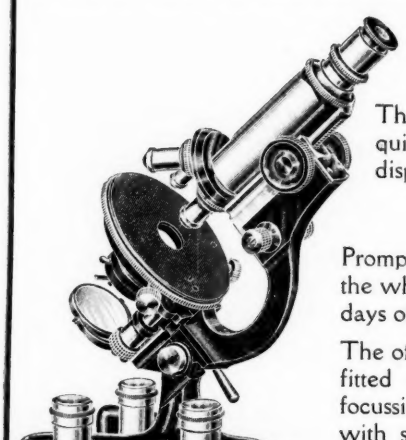

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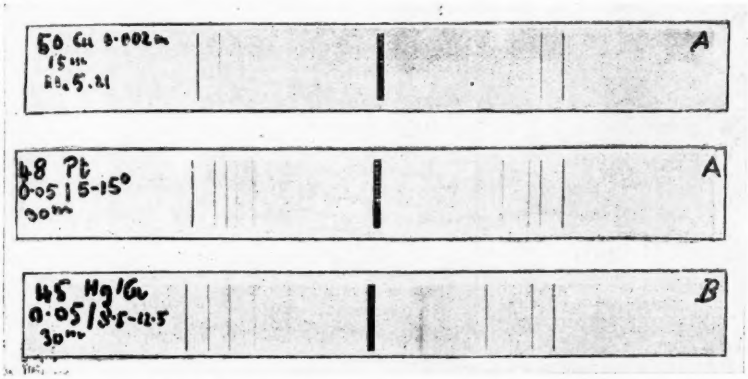

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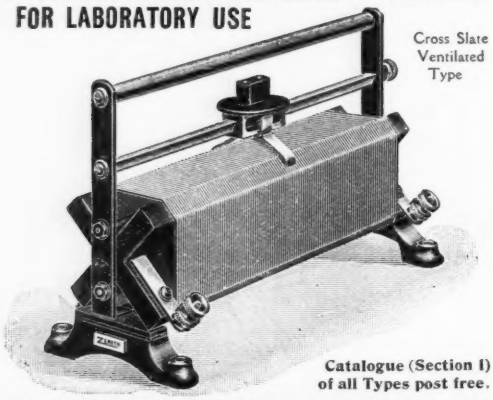

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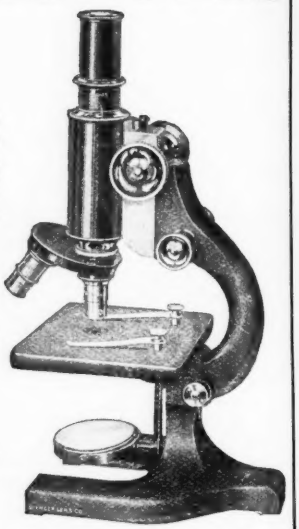

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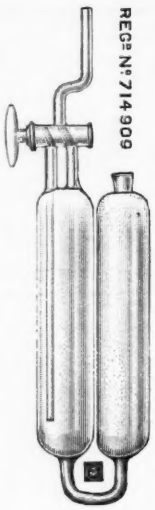

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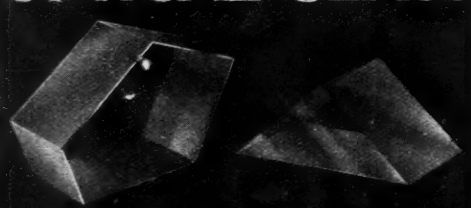

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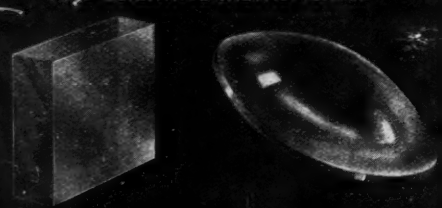

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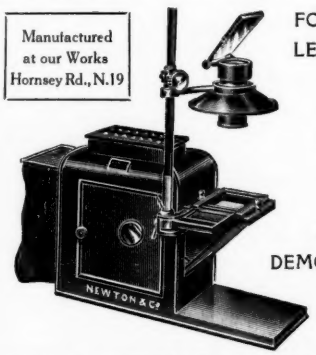

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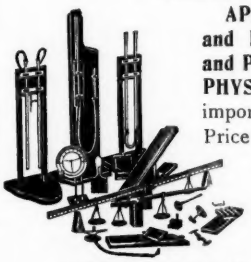

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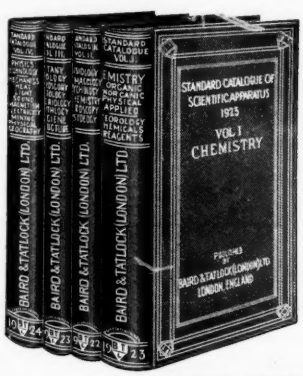

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A Course of Four Lectures on "ACTIVE AND PASSIVE IMMUNITY" will be given by Dr. R. A. O'BRIEN, C.B.E., M.D., D.P.H. (Director of the Wellcome Physiological Research Laboratories), at UNIVERSITY COLLEGE HOSPITAL MEDICAL SCHOOL (University Street, Gower Street, W.C.1), on Mondays and Fridays, March 1, 5, 8, and 12, at 5 P.M. At the First Lecture the Chair will be taken by Professor A. E. BOYCOTT, F.R.S., Graham Professor of Pathology in the University.

A Course of Three Lectures on "ATOMISTIC PHYSICS" will be given (in English) by Professor A. SOMMERFELD (Professor of Physics in the University of Munich) in the Physics Theatre of the IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY (Imperial Institute Road, South Kensington, S.W.7) on Wednesday, March 3, Tuesday, March 9, and Wednesday, March 10, 1926, at 5.30 P.M. At the First Lecture the Chair will be taken by Professor O. W. RICHARDSON, F.R.S., Professor of Physics in the University.

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A Course of Three Lectures on "SOME PRINCIPLES OF THERAPEUTICS" will be given by Professor D. MURRAY LYON, M.D., D.Sc., F.R.S.Ed. (of the Royal Infirmary, Edinburgh), at ST. THOMAS'S HOSPITAL MEDICAL SCHOOL (Albert Embankment, S.E.1), on Monday, Tuesday, and Wednesday, February 22, 23, and 24, at 5.30 P.M. At the First Lecture the Chair will be taken by Professor H. MACLEAN, M.D., D.Sc., Professor of Medicine in the University.

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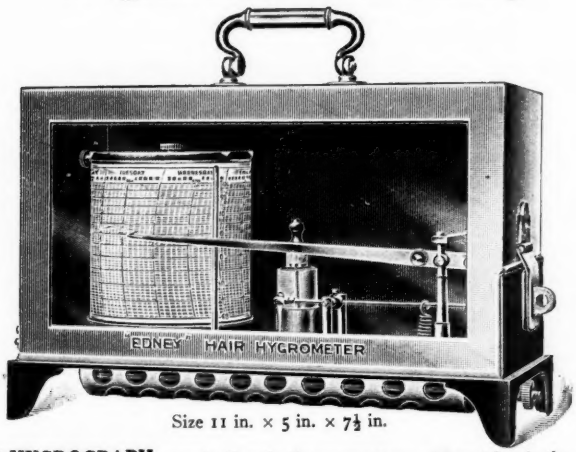

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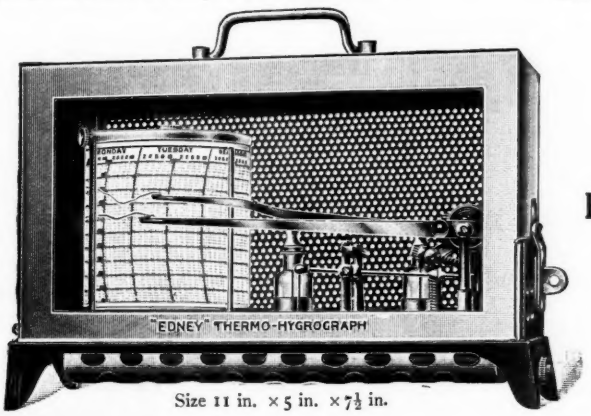

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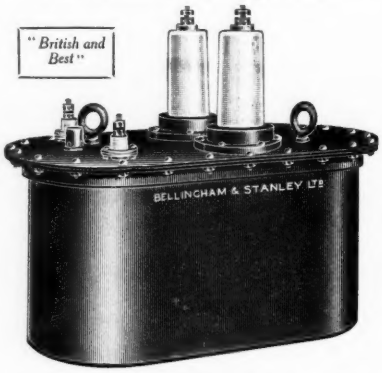

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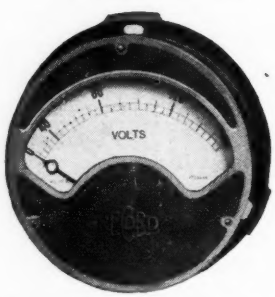

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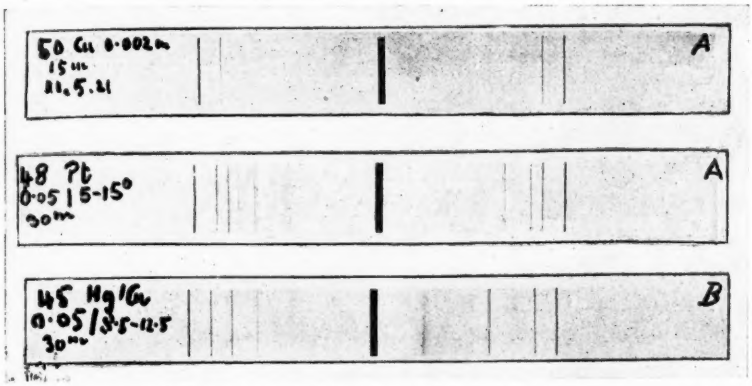

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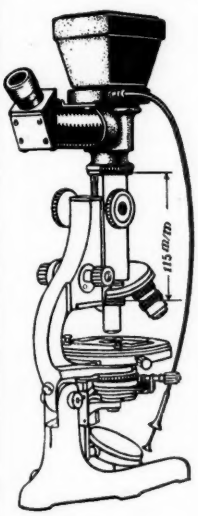

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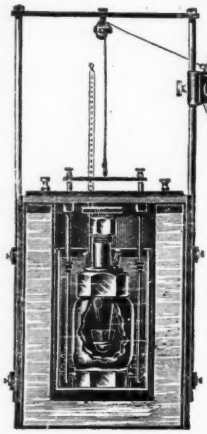

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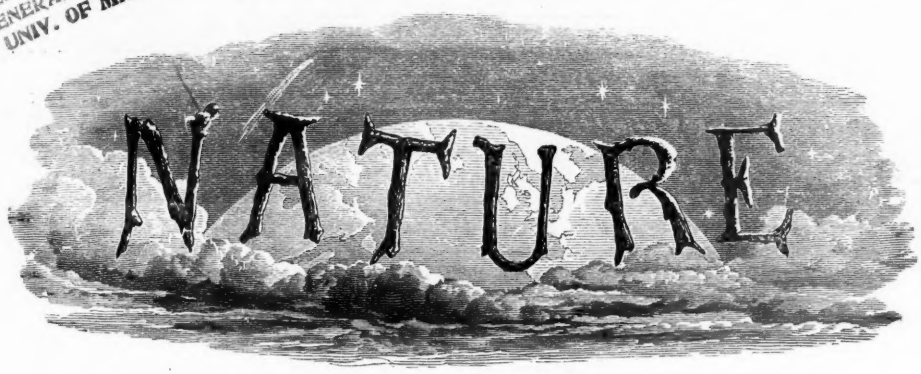

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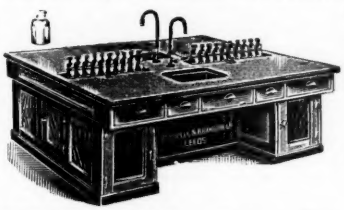

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A Course of Three Lectures on "ATOMISTIC PHYSICS" will be given (in English) by Professor A. SOMMERFELD (Professor of Physics in the University of Munich) in the Physics Theatre of the IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY (Imperial Institute Road, South Kensington, S.W.7) on Wednesday, March 3, Tuesday, March 9, and Wednesday, March 10, 1926, at 5.30 P.M. At the First Lecture the Chair will be taken by Professor O. W. RICHARDSON, F.R.S., Professor of Physics in the University.

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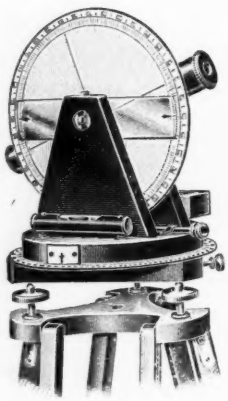

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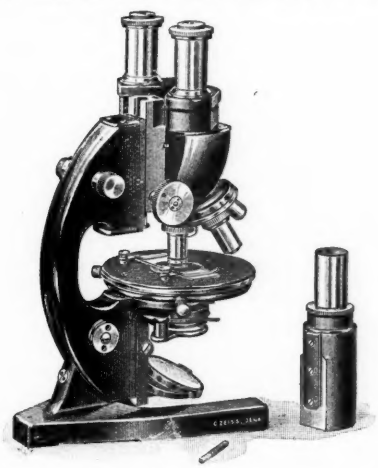

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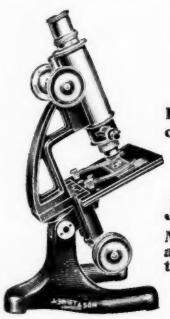

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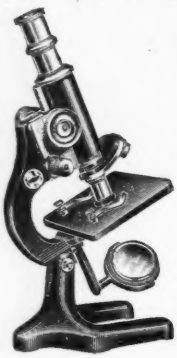

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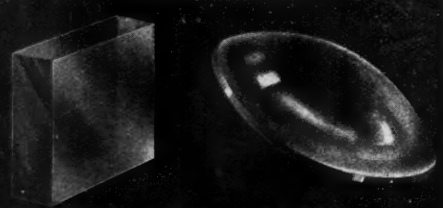

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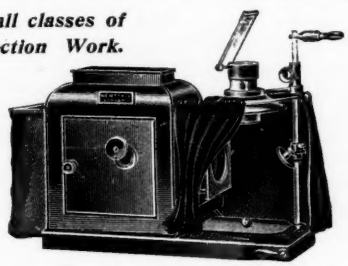

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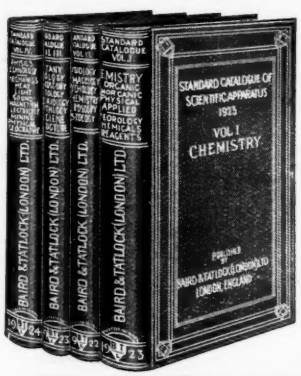

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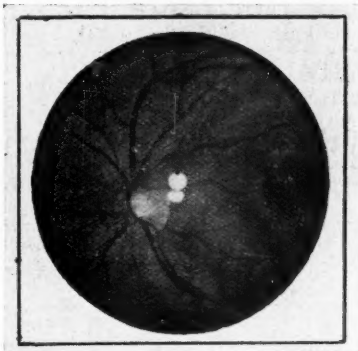

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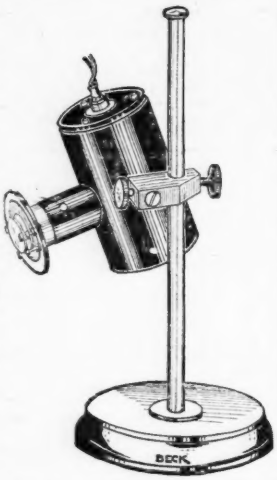

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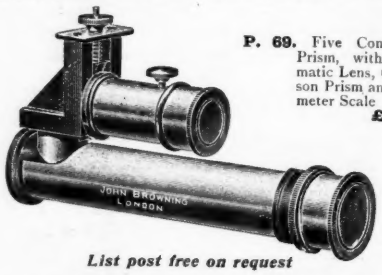

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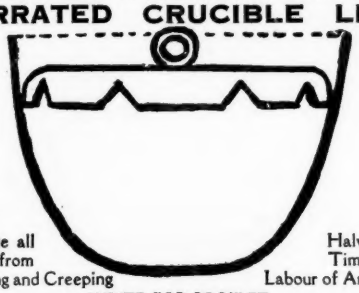

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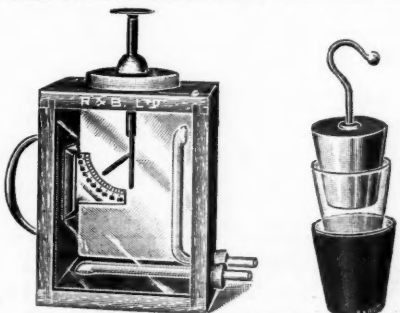

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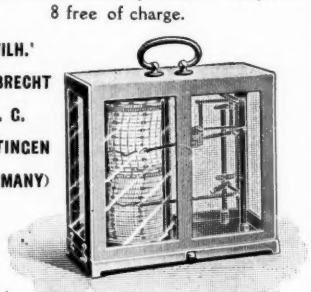

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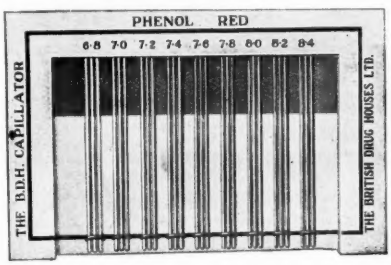

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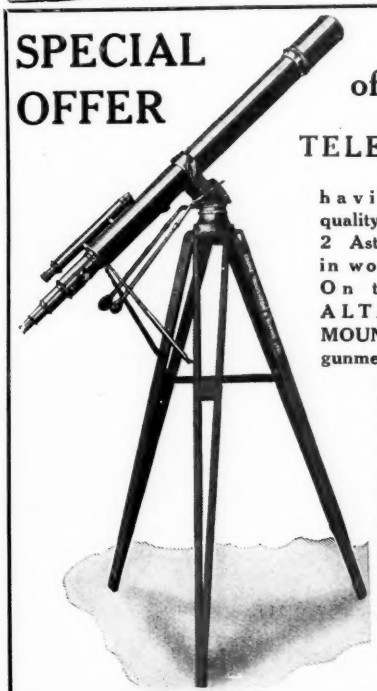

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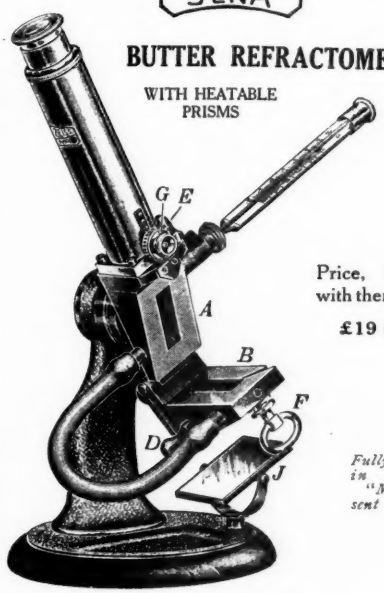

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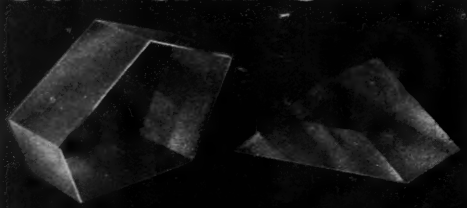

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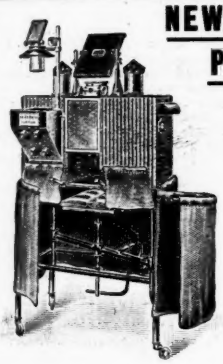

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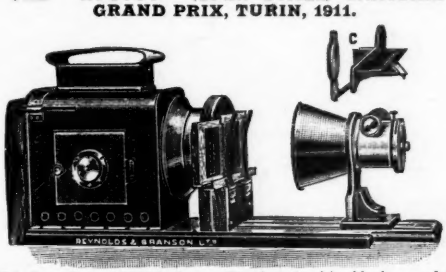

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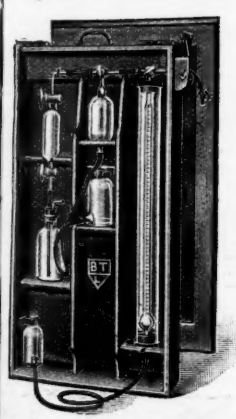

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Guildhall, Hull, February 19, 1926. J. T. RILEY, Secretary.

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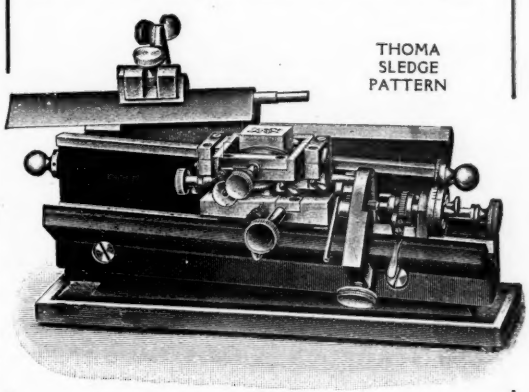

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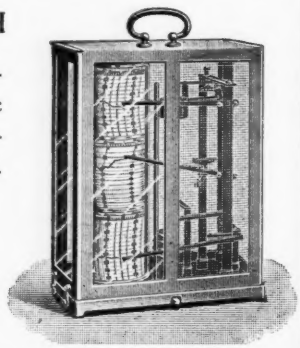

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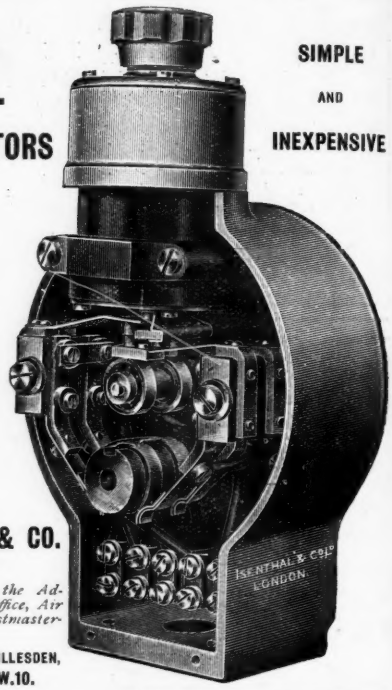

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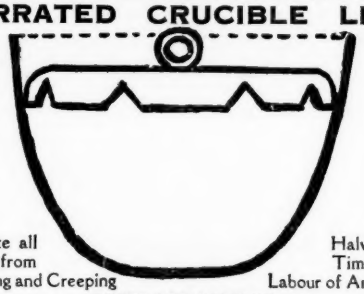

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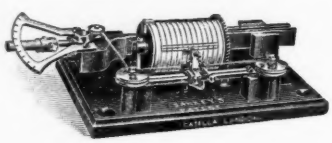

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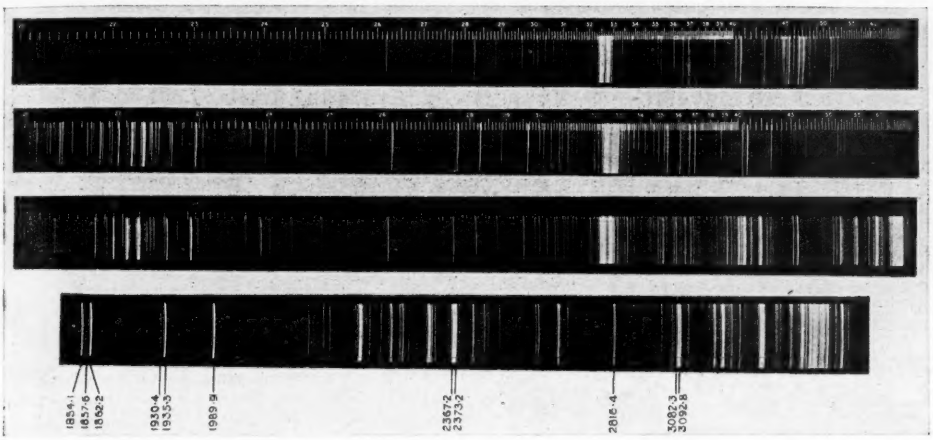

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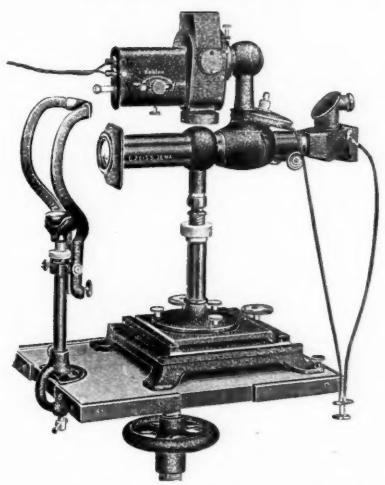

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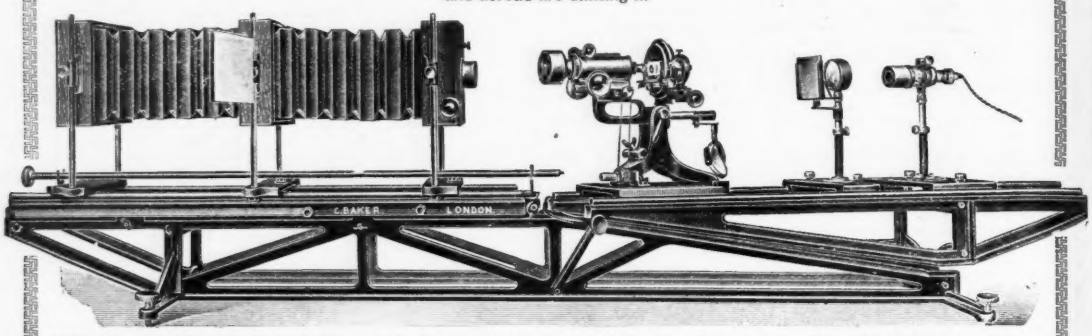

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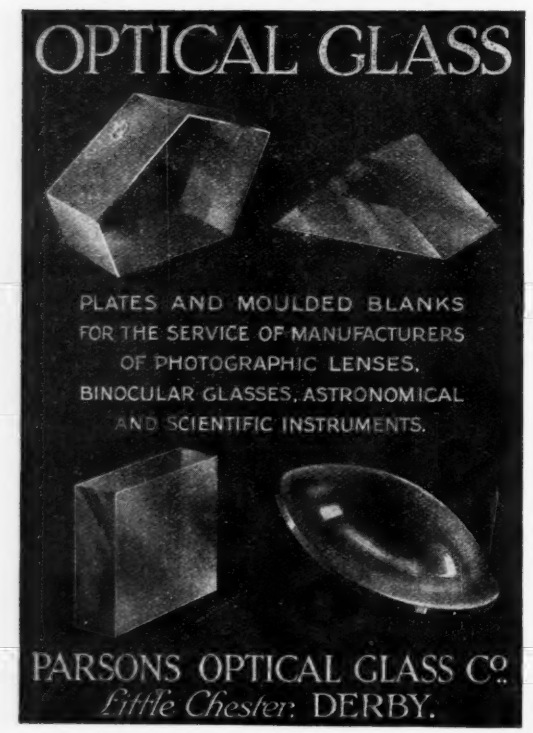

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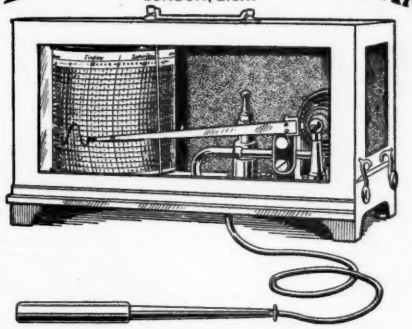

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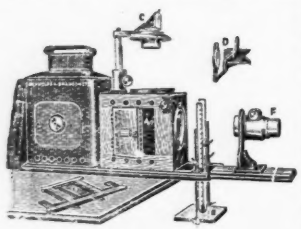

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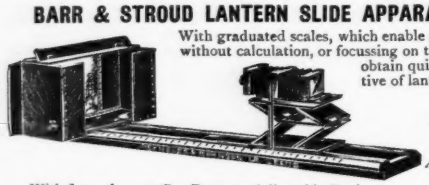

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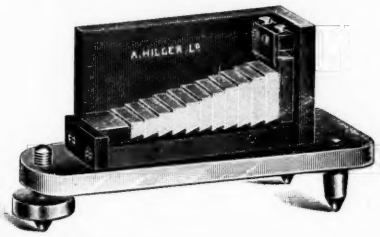

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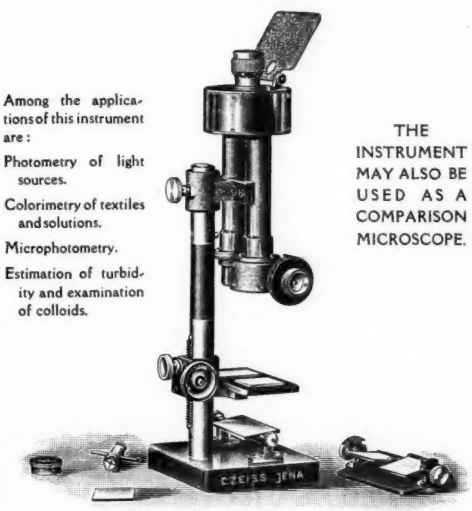

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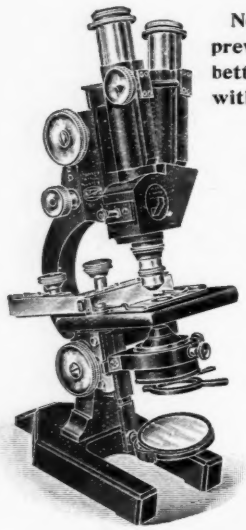

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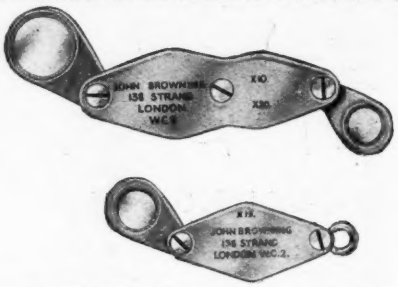

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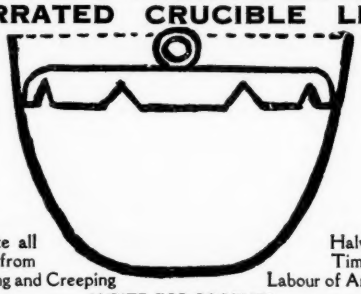

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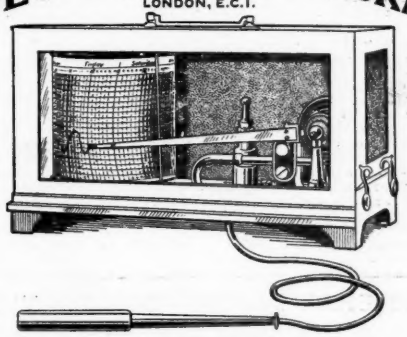

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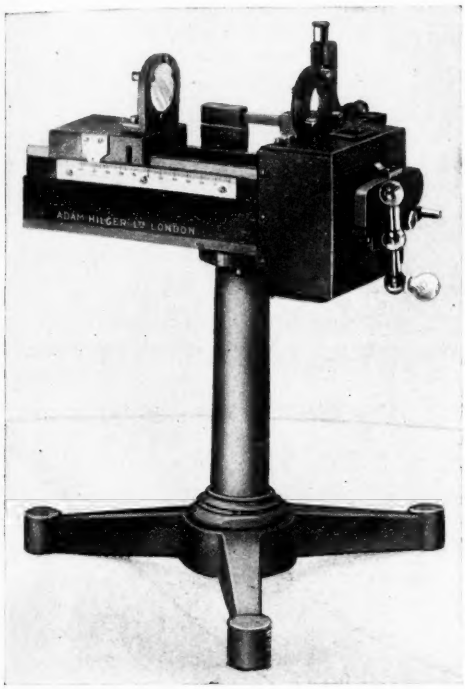

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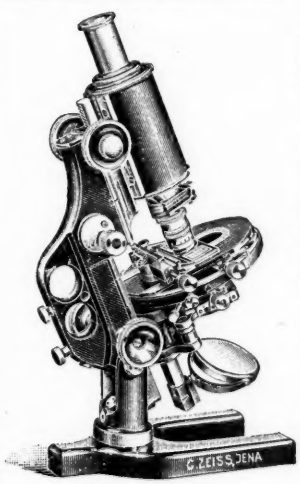

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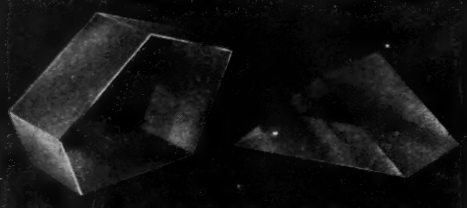

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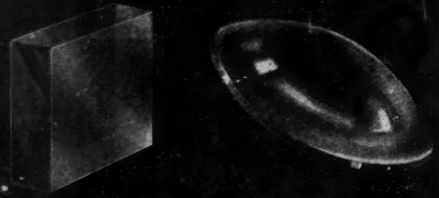

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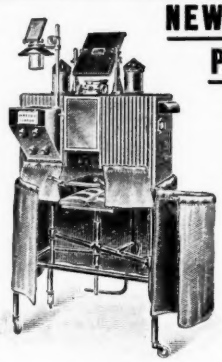

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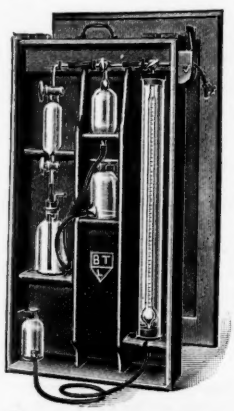

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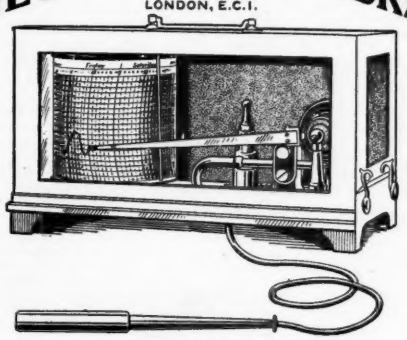

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Candidates must be not less than 22 and not more than 26 years of age, but candidates who have served in H.M. Forces between August 4, 1914, and November 11, 1918, may deduct from their actual age any period of such service between August 4, 1914, and December 31, 1919. They must be graduates in science of a British University, and special consideration will be given to candidates who have received a sound general scientific training and graduated with honours in Zoology.

The salary of the post is £200 per annum plus the Civil Service Cost of Living Bonus, which at the current rate amounts to about £113. The probationary period will be two years, and if the appointment is confirmed at the end of that period it will become an established one, on a scale of salary of £250-£15-£400 plus Civil Service Cost of Living Bonus.

APPOINTMENT OF TECHNICAL ASSISTANT ON THE SCIENTIFIC STAFF.

The Board also invite applications for one post as TECHNICAL ASSISTANT on their Scientific Staff. Candidates must be between 18 and 24 years of age, but those who have served in H.M. Forces during the war may deduct from their actual age any period of such service between August 4, 1914, and December 31, 1919. They must have gained the Leaving Certificate of the Scottish Education Department or have passed an examination of equivalent standard.

Salary £100 rising by annual increments of £7: 10s. to £115 and then by £10 to £250 plus Civil Service Cost of Living Bonus. Such bonus at the current rate on £100 is £76.

Forms of application and copies of the Regulations affecting the above appointments may be obtained from the SECRETARY, Fishery Board for Scotland, 101 George Street, Edinburgh, with whom applications must be lodged not later than May 9, 1926.

Edinburgh, April 6, 1926.

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LEAVE.—Leave on full salary normally granted after tour of from 20 to 30 months to an amount of six days for each completed month of residence (or of three days if officer not returning to East Africa), exclusive of periods of voyages.

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Applications for further particulars and forms of application should be addressed in writing to the PRIVATE SECRETARY (APPOINTMENTS) COLONIAL OFFICE, 38 Old Queen Street, Westminster, S.W.1.

A candidate abroad, if resident in a Dominion or Colony, should apply for a form of application to the Governor-General or Governor, but otherwise should submit the fullest particulars of his experience and qualifications supported by testimonials and references.

Completed applications should be received by the Private Secretary not later than August 1, 1926.

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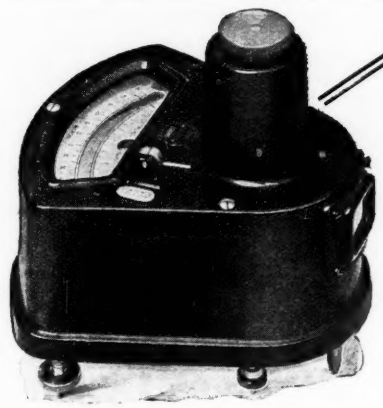

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Last date for receiving applications :—May 8.

For further information apply the undersigned.

OLIVE E. MONKHOUSE, Secretary.

TWO LABORATORY ASSISTANTS are

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Further information to be obtained from the SECRETARY, Foot-and-Mouth Disease Research Committee, Ministry of Agriculture and Fisheries, 10 Whitehall Place, London, S.W.1.

SUDAN GOVERNMENT.

The Department of Agriculture and Forests requires the services of an ASSISTANT PLANT BREEDER. Candidates must be men of British nationality and must be in possession of a University Degree in Pure Science or Agriculture. If the former, they should have had some special training in Agriculture, preferably in the Tropics. Candidates must be between the ages of 23 and 30 and unmarried. Commencing salary £480 per annum with allowances. The successful candidate will be required to take up his duties in the Sudan on June 20, 1926, and all applications addressed below must be received not later than May 7, 1926. Particulars of appointment and terms of service may be obtained from THE CONTROLLER, Sudan Government London Office, Wellington House, Buckingham Gate, S.W.1.

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Persons desirous of being candidates for this appointment are invited to communicate with the SECRETARY to the Board, from whom further particulars may be obtained.

Applications should be received not later than May 1, 1926.

Guildhall, Hull, February 19, 1926. J. T. RILEY, Secretary.

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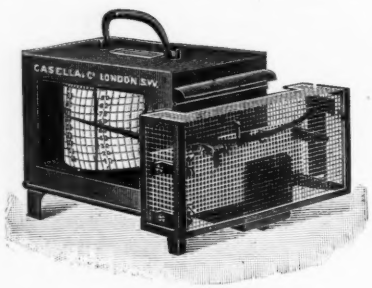

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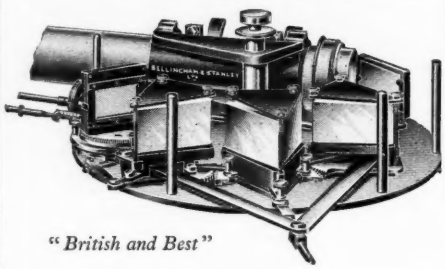

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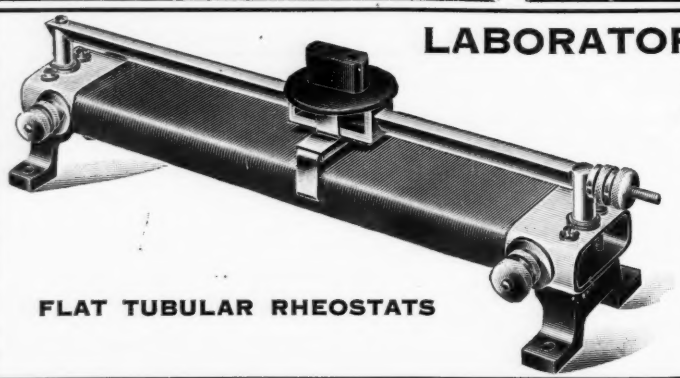

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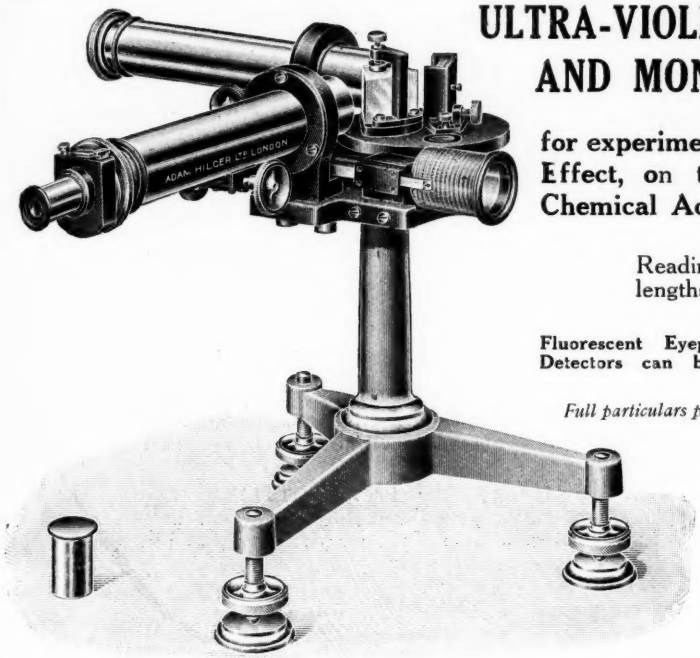

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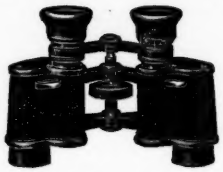

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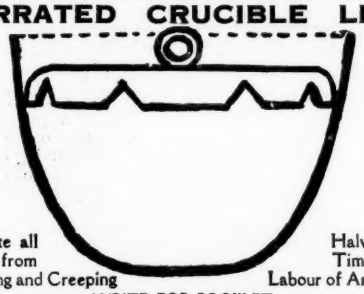

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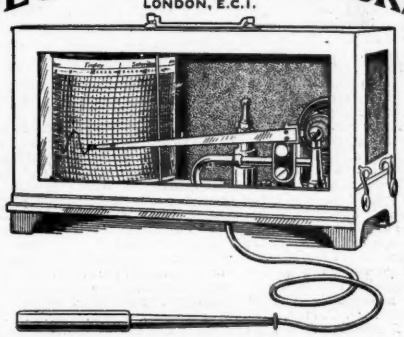

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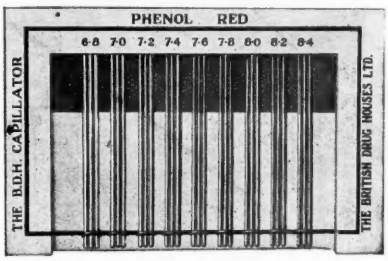

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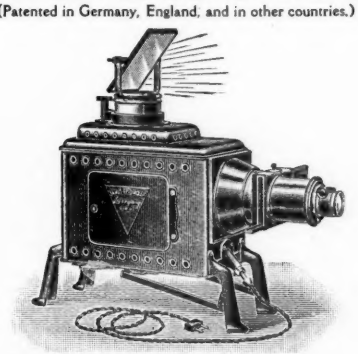

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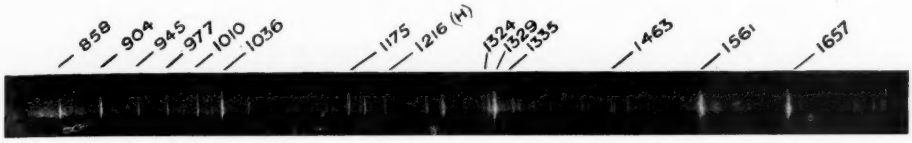

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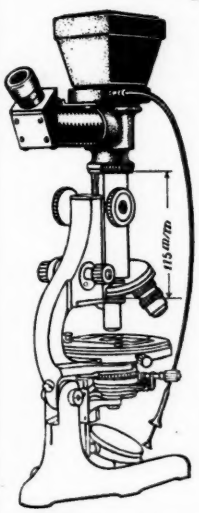

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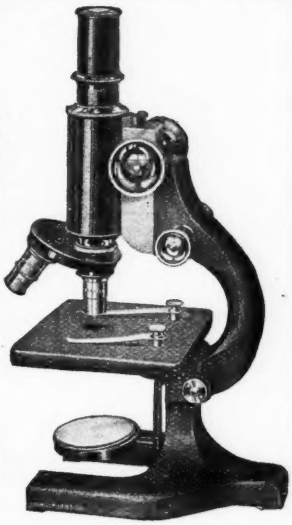

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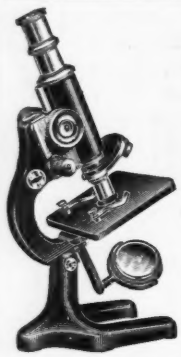

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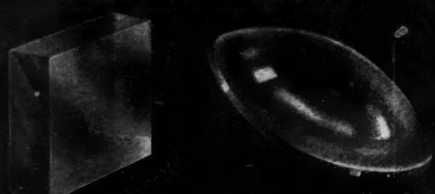

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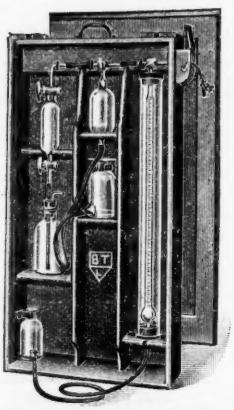

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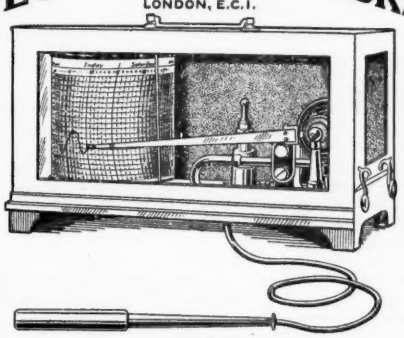

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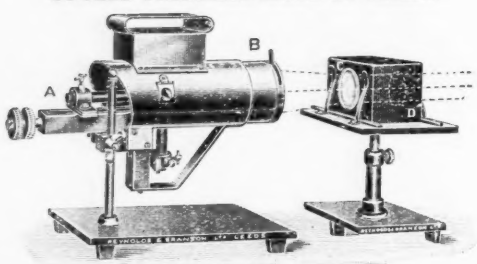

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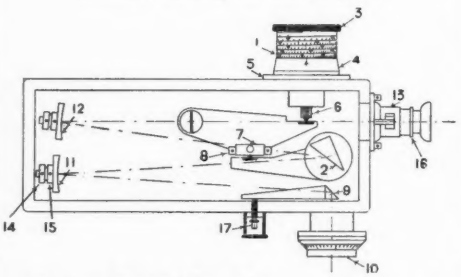

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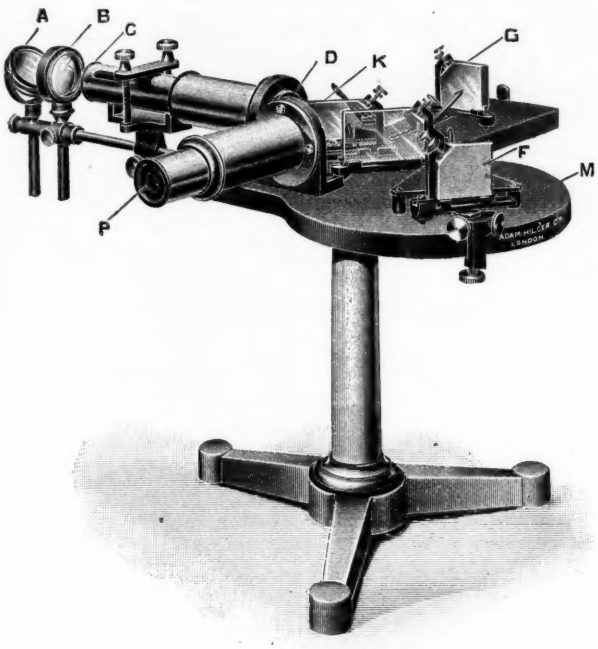

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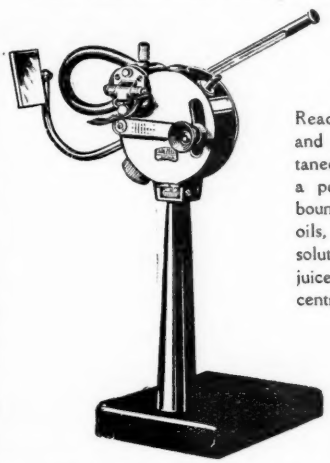

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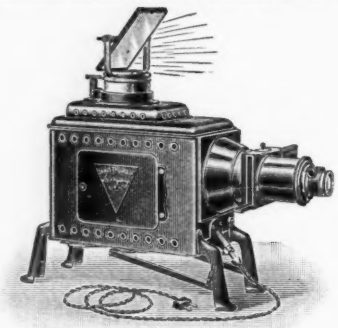

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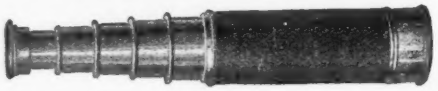

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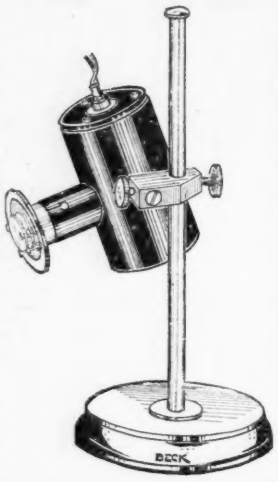

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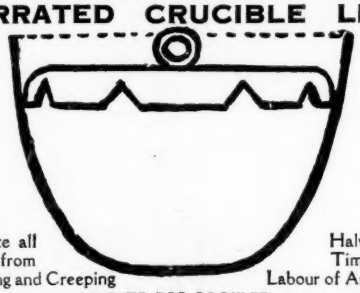

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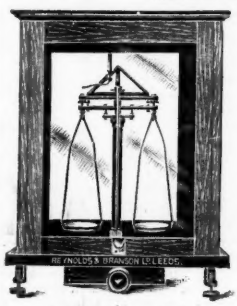

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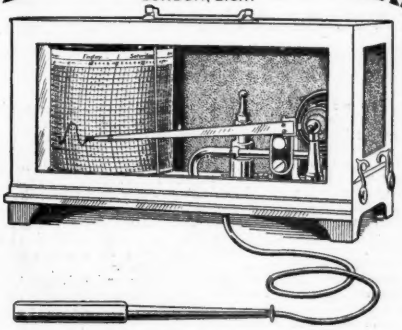

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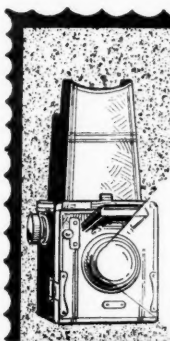

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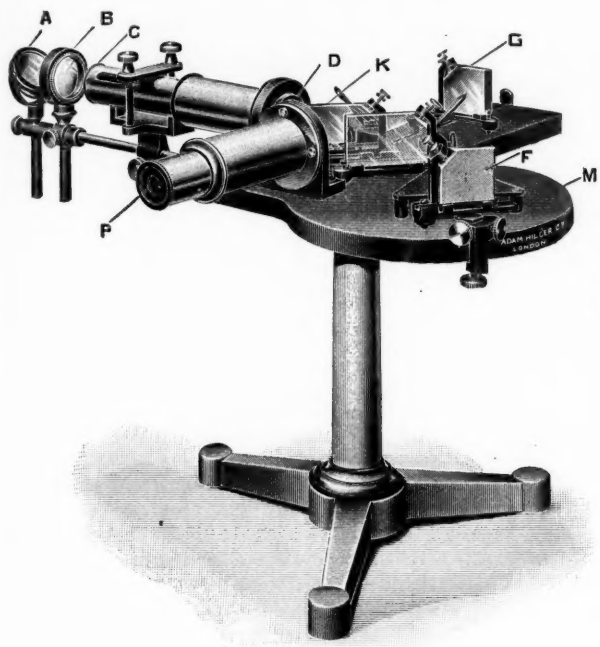

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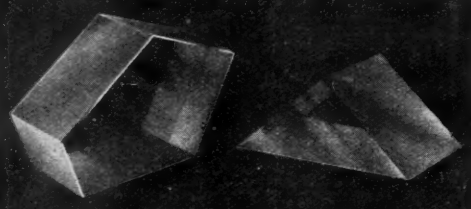

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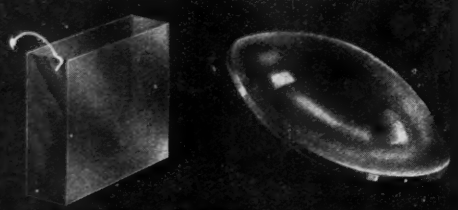

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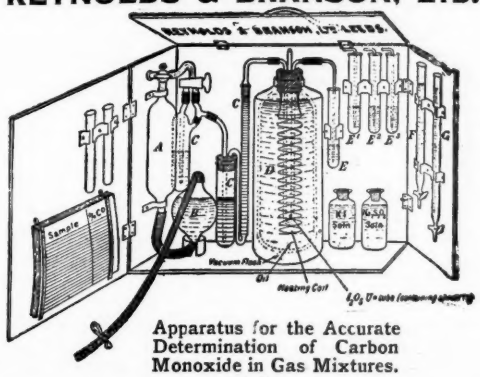

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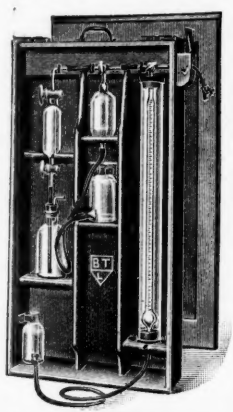

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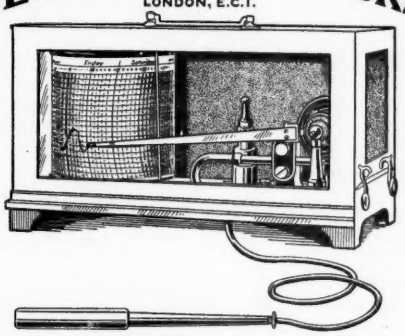

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(1) Fellowship in Classics.

The Warden and Fellows of New College propose to elect not later than October next to an official FELLOWSHIP IN CLASSICS. The candidate elected will be required to undertake part of the Classical teaching and examinations of the College. His duties will begin in Michaelmas Term next, unless the College should grant him leave of absence for study abroad before commencing his work.

Candidates are requested to communicate with the Warden by letter before June 5, 1926, sending three recent testimonials and also mentioning two other persons to whom reference can be made.

Further details of the appointment may be obtained from the WARDEN.

(2) Fellowship in Physics.

The Warden and Fellows of New College propose to elect not later than October next to an official FELLOWSHIP IN PHYSICS. The candidate elected will be required to undertake the teaching work of the College in Physics, and to assist in teaching other sciences involving a knowledge of Physics, and to take part in the ordinary College examinations.

Candidates are requested to communicate with the Warden by letter before June 5, 1926, sending three recent testimonials and also mentioning two other persons to whom reference can be made.

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April 30, 1926.

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The appointment will be made by the Minister for Lands and Agriculture on the recommendation of the Civil Service Commissioners, who will investigate the qualifications of candidates with the assistance of a Selection Board appointed by the Commissioners. Candidates may be required to attend in person before the Board. Applications must be made on the prescribed form, copies of which, together with full particulars, may be obtained from the SECRETARY, Civil Service Commission, 33 St. Stephen's Green, Dublin, to whom the forms duly completed should be returned so as to reach him not later than May 31, 1926.

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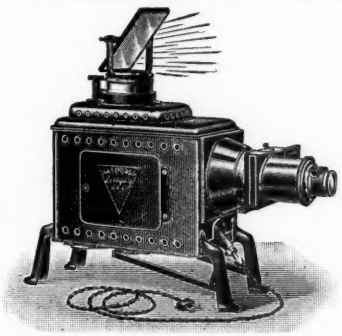

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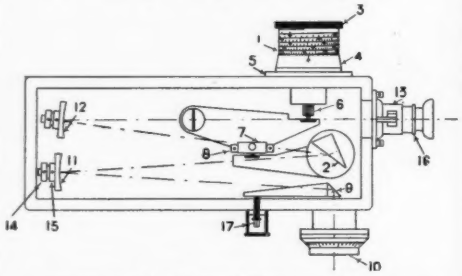

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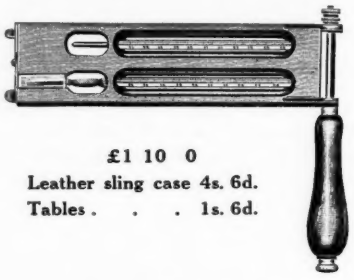

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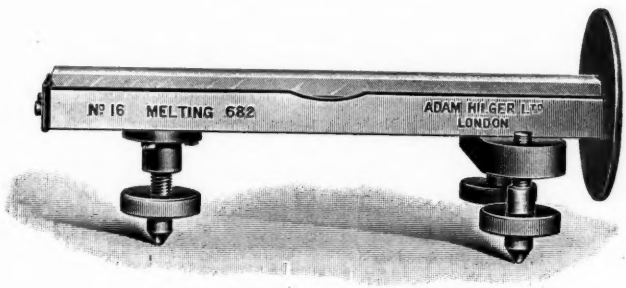

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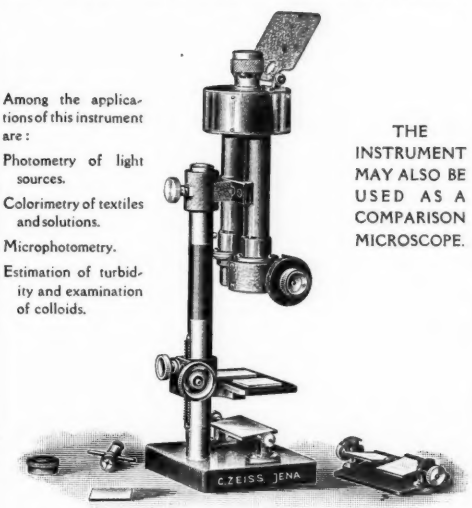

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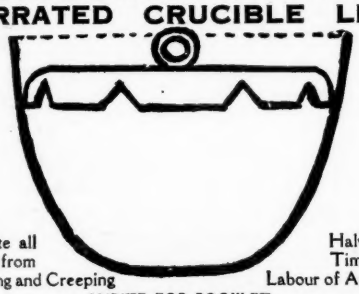

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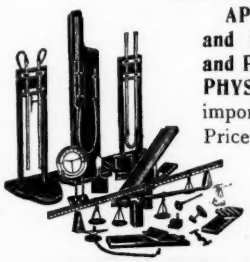

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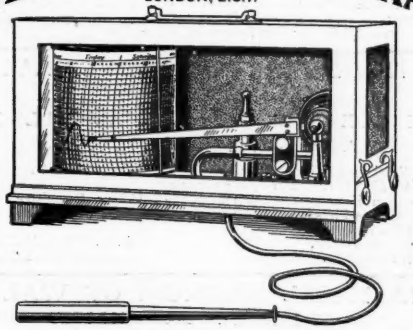

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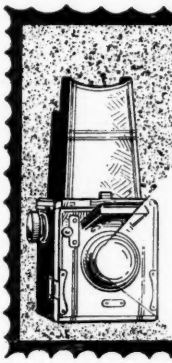

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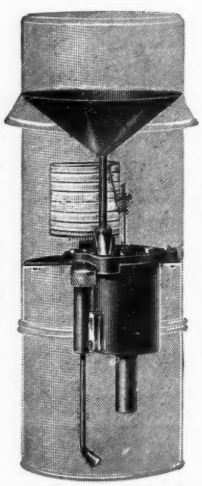

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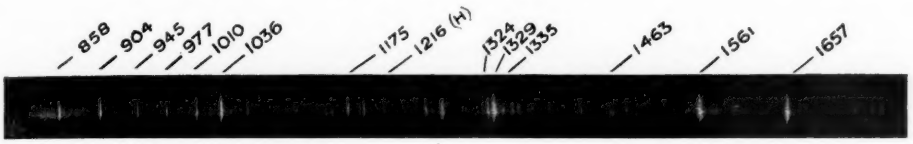

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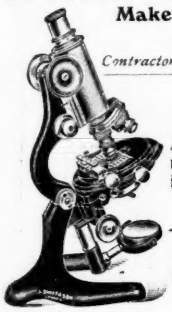

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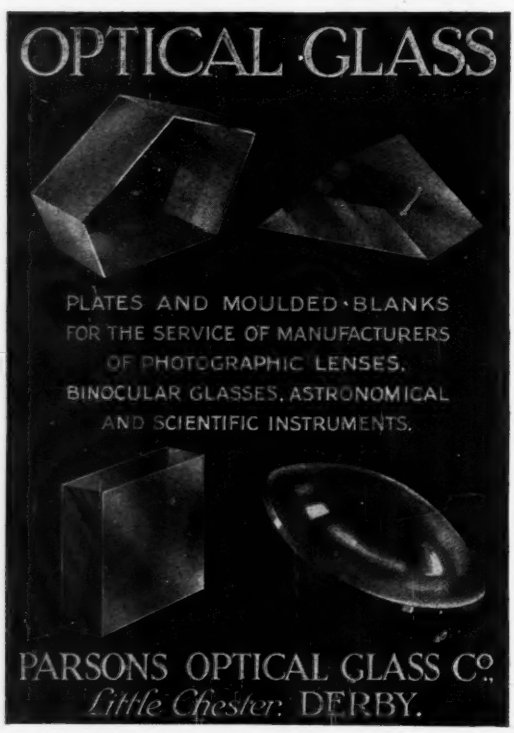

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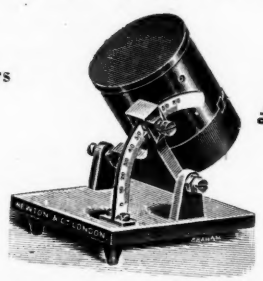

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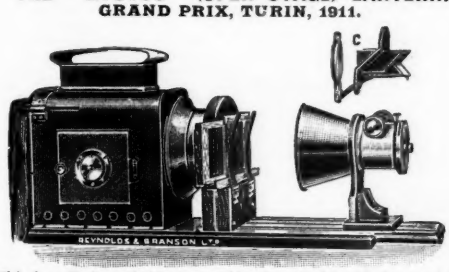

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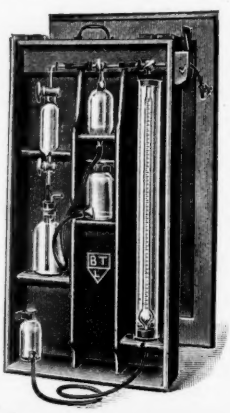

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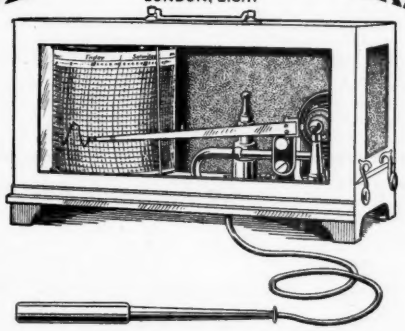

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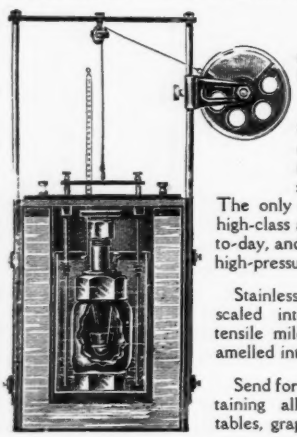

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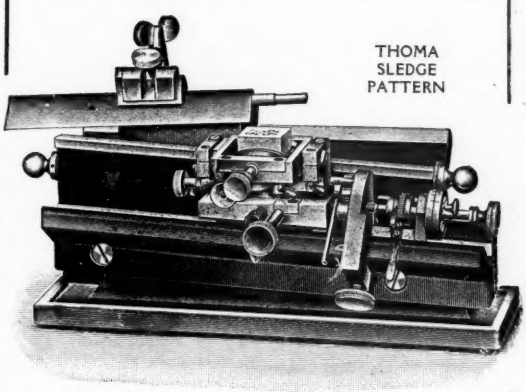

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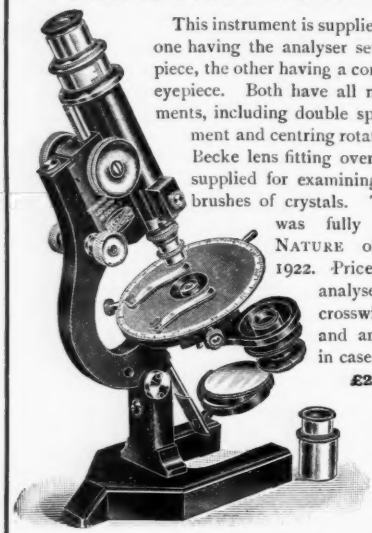

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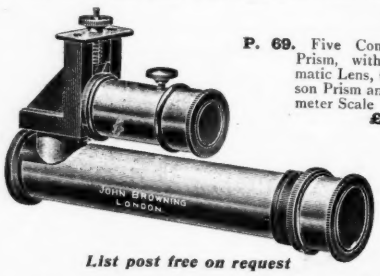

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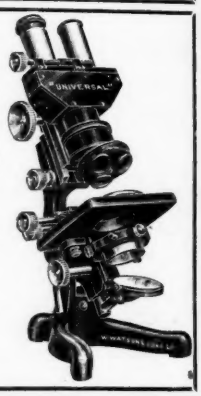

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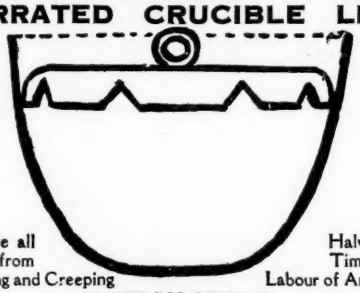

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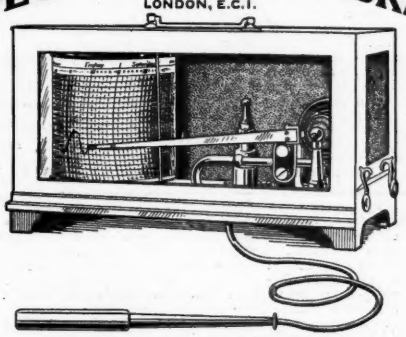

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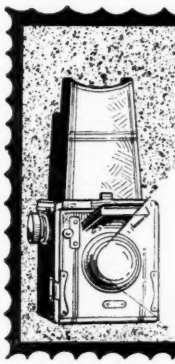

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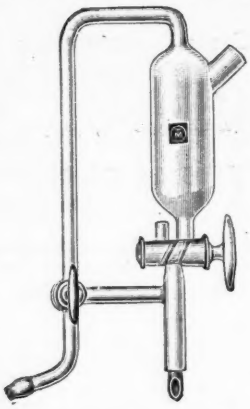

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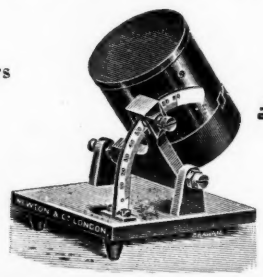

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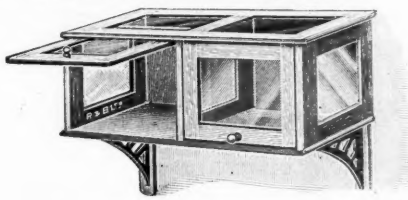

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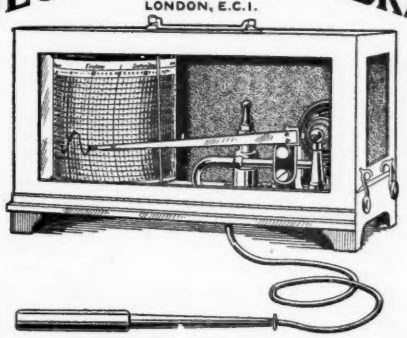

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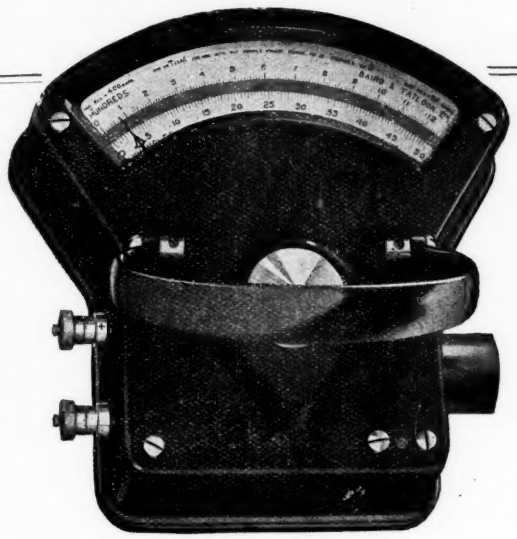

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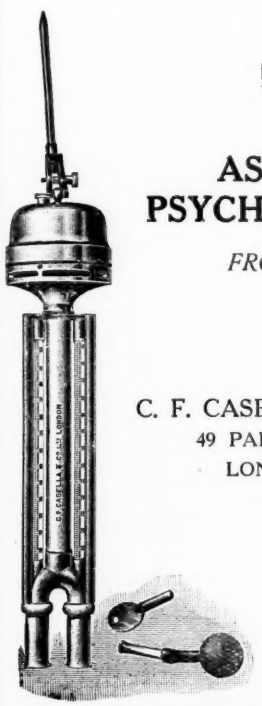

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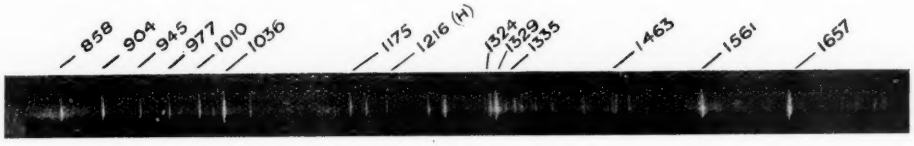

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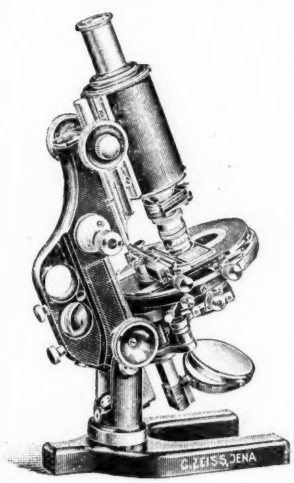

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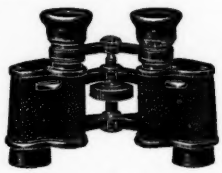

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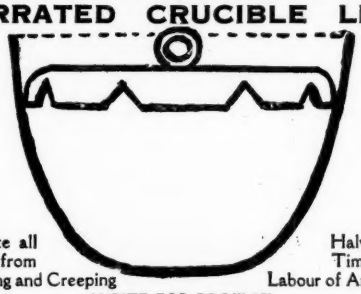

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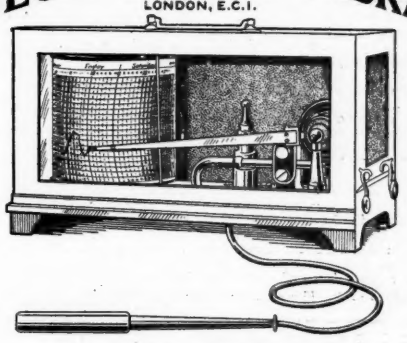

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Further particulars may be obtained from the undersigned, to whom applications should be submitted before June 30.

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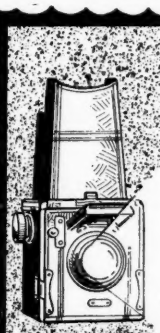

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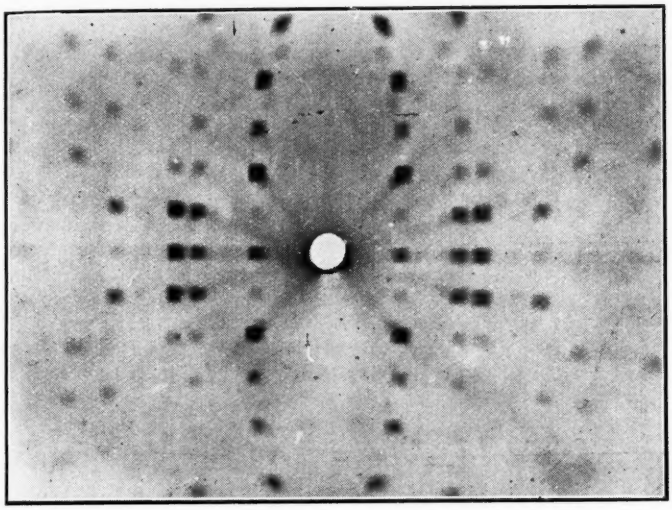

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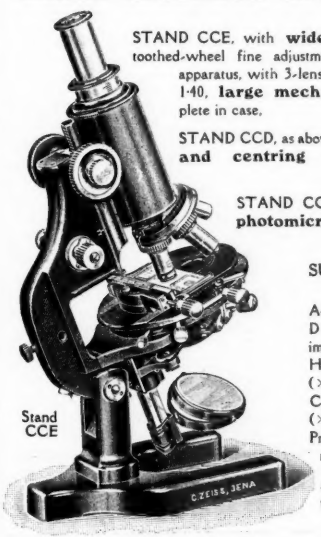

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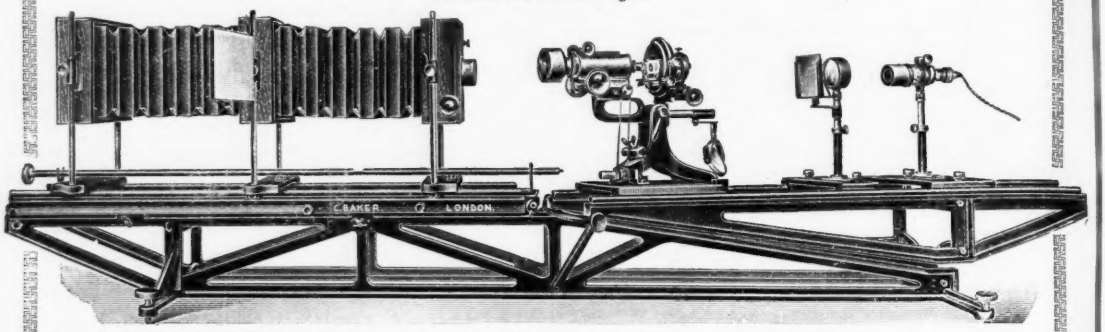

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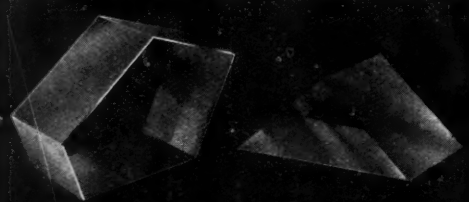

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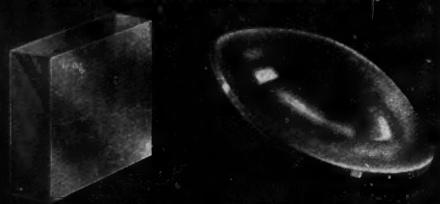

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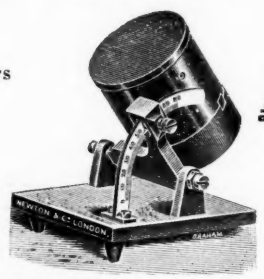

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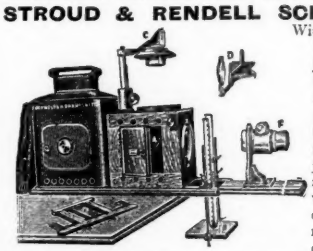

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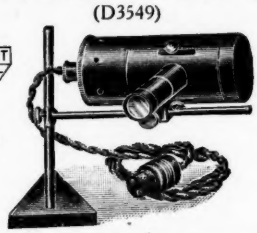

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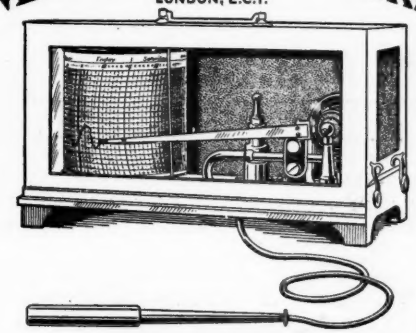

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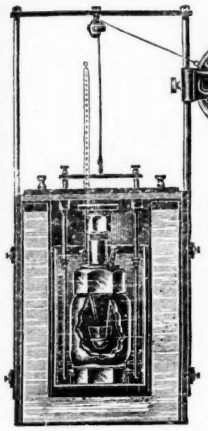

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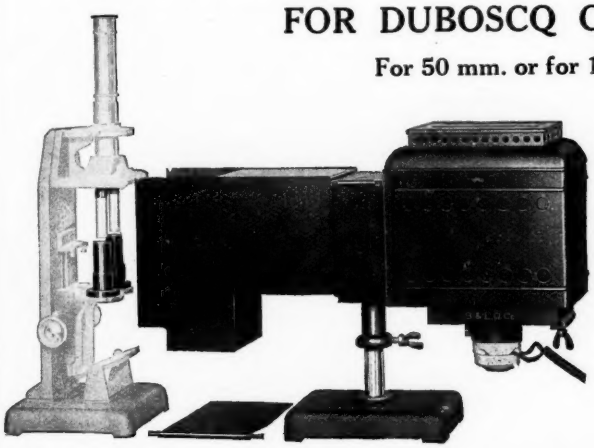

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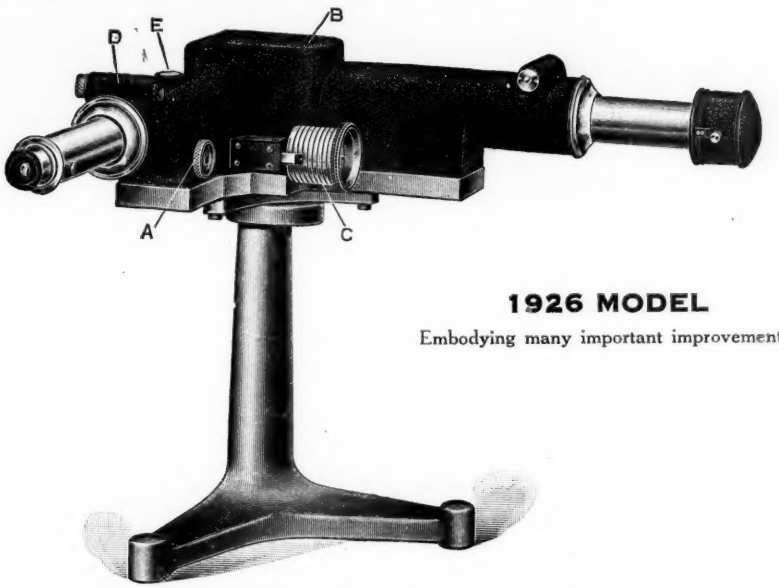

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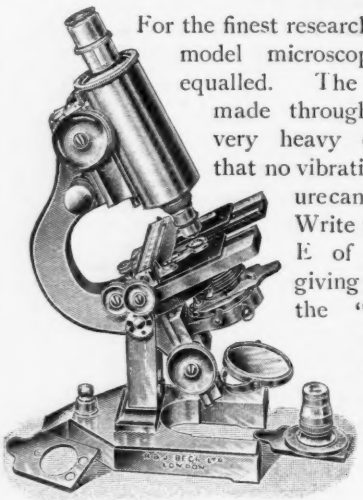

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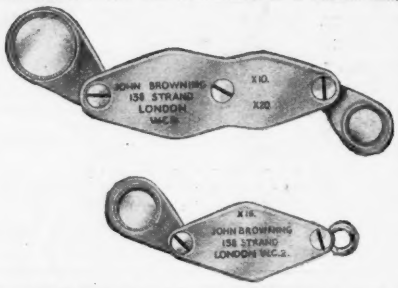

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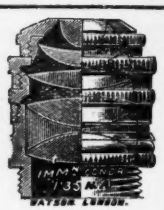

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